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U.S. Marine Corps Communication-Electronics School Training Process: Discrete-Event Simulation and Lean Options

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By: Charles R. Neu
Jon Davenport
William R. Smith

December 2007

Advisors: Susan Heath
Cary Simon
Don Summers

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13. ABSTRACT (maximum 200 words)

This paper uses discrete-event simulation modeling, inventory-reduction, and process improvement concepts to identify and analyze possibilities for improving the training continuum at the Marine Corps Communication-Electronics School (MCCES), specifically in terms of reducing adverse effects of lost-time spent in the Marines Awaiting Training (MAT) Platoon queue. Every possible improvement that the local commander could make without spending any capital was tested using the Process Analyzer Function (PAN) in Arena. The researchers also tested increasing the number of instructors up to the quantity authorized. Potential effects on the MCCES operating budget are offered, i.e., a cost-benefit analysis based on average salaries was conducted with recommendations for making the training system more efficient while examining potential changes to reduce costs.

The premise of the study is that Marines Awaiting Training (MAT) are potential warfighters not gaining value-added training nor benefiting the Marine Corps when waiting in a queue to begin Military Occupational Specialty (MOS) training, i.e., adversely affecting Fleet Marine Forces operational readiness. The study coincides with current emphasis on reducing the Training, Transients, Patients, and Prisoners (T2P2) account.

The researchers determined that changing from the present MCCES process of scheduling classes to an on-demand scheduling method, and, in some MOSs, changes to the minimum and maximum class sizes and the number of instructors, would result in a reduction in the average days spent in MAT and the average number of Marines in MAT. By utilizing all recommendations, the researchers identified a potential value savings in terms of salary of $11.6 million and a potential cost savings to the barracks and base support costs of $1.9 million.

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U.S. MARINE COMMUNICATION-ELECTRONICS SCHOOL TRAINING PROCESS: DISCRETE EVENT SIMULATION AND LEAN OPTIONS

Charles R. Neu, Lieutenant Commander, Supply Corps, United States Navy
Jon Davenport, Major, United States Marine Corps
William R. Smith, Captain, United States Marine Corps

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Researchers: ______________________________________
Charles R. Neu

____
Jon Davenport

____
William R. Smith

Approved by: ______________________________________
Susan Heath, Associate Professor

____
Dr. Cary Simon, Lecturer

____
Don Summers, Senior Lecturer

____
Robert N. Beck, Dean
Graduate School of Business & Public Policy

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LIST OF ACRONYMS AND ABBREVIATIONS

ABC	Activity-based Costing
CC	Critical Chain
CCR	Capacity-constrained Resource
CDD	Course Descriptive Data
CI	Continuous Improvement
CIP	Continuous Improvement Program
CMC	Commandant of the Marine Corps
CT	Cycle-time
C4	Command, Control, Communications, and Computers
DBR	Drum-Buffer-Rope
DEP	Delayed Entry Program
DOD	Department of Defense
FIFO	First-in First-out
FMF	Fleet Marine Force
FROC	Field Radio Operator’s Course
FWC	Field Wire Course
FY	Fiscal Year
HQMC	Headquarters Marine Corps
IA	Individual Augmentation
LAN	Local Area Network
LCpl	Lance Corporal
MAT	Marines Awaiting Training
MCAGCC	Marine Corps Air Ground Combat Center
MCCDC	Marine Corps Combat Development Command
MCCES	Marine Corps Communication-Electronics School
MCMAP	Marine Corps Martial Arts Program
MCRC	Marine Corps Recruiting Command
MCRD	Marine Corps Recruit Depot
MCT	Marine Combat Training

MEOC	Multi-channel Equipment Operator’s Course
MOS	Military Occupational Specialty
MTT	Mobile Training Team
NAVAIR	Naval Air Systems Command
NAVSEA	Naval Sea Systems Command
NCO	Non-commissioned Officer
OMB	Office of Management and Budgeting
PAN	Process Analyzer
Pvt	Private
SOI	School of Infantry
SOP	Standard Operating Procedures
SSE	Sum of Squares Error
TAD	Temporary Additional Duties
TDNOC	Tactical Data Network Operator’s Course
TDSOC	Tactical Data Systems Operator’s Course
TECOE	Training and Education Center of Excellence
TECOM	Training and Education Command
TH	Throughput
TMEOC	Transportable Multi-channel Operator’s Course
TIP	Training Input Plan
TOC	Theory of Constraints
T2	Training and Transients
T2P2	Training, Transients, Patients and Prisoners
ULCSOMC	Unit-level Circuit Switch Operator’s Maintenance Course
WIP	Work in process
WTR	Warfighter Training Request

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I. INTRODUCTION

A. BACKGROUND

Marine Corps Communication-Electronics School (MCCES), located in Twentynine Palms, California, is a formal learning center that provides the Marine Corps Operating Forces with entry-level and career-progression training for enlisted Marines in the communications occupational field.[1] The researchers' premise is that Marine communicators are a crucial component of the Marine Corps' ability to fight the nation's battles, and any amount of time a Marine spends waiting for training is time lost for the Operating Forces which degrades readiness.

One of the underlying goals of MCCES is to reduce the cycle-time of Marines by moving them through the training continuum as efficiently as possible within the constraints of each particular course. There are limited resources available to train the Marines that cycle through Company B entry-level schools each year. One MCCES representative stated that analyzing these resources objectively and quantitatively has yet to be done. Consequently, there may be inefficiencies that, once identified, could be "Leaned" out of the system or improved upon to reduce the time that Marines spend in the training continuum.

B. RESEARCH PROJECT OBJECTIVE

This project examines the entry-level training continuum at Company B, MCCES. The first goal of the study was to accurately simulate the flow for the entry-level courses at Company B, MCCES, using Rockwell's Arena Software. Each of the seven entry-level Military Occupational Specialties (MOS) were simulated, and potential bottlenecks were identified. Utilizing the Arena Process Analyzer, the resource structure and information sharing for each MOS was explored to decrease time spent in the Marines

[1] Twentynine Palms is not the only location Marines receive entry-level 06XX training. MOS 0613 (Construction Wireman) are trained at Sheppard AFB, TX, and MOS 0627 (Ground Mobile Forces SATCOM Operator) are trained at Fort Gordon, GA.

Awaiting Training (MAT) queue. The goal was to present recommendations to the command to improve the process efficiency at Company B, MCCES, and to demonstrate potential cost savings and recapitalization with essentially no capital expenditure.

C. RESEARCH QUESTIONS

Based on the researchers' process-improvement and combined military experience, an underlying premise is that the implementation of process-improvement methods are critical to efficiently operating in a fiscally constrained environment - the norm in a wartime military. Modern advances in simulation and modeling software can make the practice of process improvement more practical and realistic. This study was designed to reveal potential bottlenecks and their causes at Company B, MCCES, then apply the above techniques to recommend meaningful improvements in the training continuum. The following questions apply:

1. What benefits can simulation modeling provide to MCCES and how much, if any, can each course's cycle-time, average total number of Marines in the system, and average total time spent in the system be reduced?

2. What is the most restrictive bottleneck in the training process at MCCES?

3. What are the cost benefits to reducing the time spent in the MAT queue?

4. What changes can MCCES implement to improve the efficiency of each MOS training continuum?

5. To what extent can the local command implement system changes, particularly if or when increased numbers of MCCES students are anticipated?

6. What lessons learned at MCCES are applicable to other Marine Corps training commands?

D. SCOPE

The scope of this project focuses on the training process at MCCES. Analysis of the models' output and recommendations for MCCES may require policy changes by Training and Education Command. No attention is given to training schedules or recruiting processes external to MCCES. Although the outputs of Marine Corps Recruit Depot (MCRD) and Marine Combat Training (MCT) are inputs to MCCES, analyzing those processes are beyond the scope of this paper.

E. METHODOLOGY

Currently, Marine Corps Communication-Electronics School (MCCES) experiences a high volume of Marines waiting in queue for their training to commence. The existing system is modeled, and applicable performance measures and associated costs are illustrated. Recommendations are made to improve throughput, reduce waiting time, and illustrate the cost-benefit analysis of those recommendations. Theory of Constraints and Little's Law are applied, among others, to the MCCES training process, and potential effects of these theories relating to throughput, cycle-time, and time spent in queue are offered. Using private industry inventory management and industry production approaches (simulation modeling tools), recommendations for process improvement are derived. The study examines how theoretical method application – Theory of Constraints and Lean methodology – can contribute to increased theoretical capacity, efficiency, and reduced costs.

Through the development and analysis of a simulation model and application of accepted theory and business practices, the objectives of the study are met including demonstrating the effects of removing bottlenecks and improving the efficiency of the Company B's current system. By utilizing Lean, Theory of Constraints, Activity-based Costing, and Continuous Improvement methods, proposed recommendations can reduce cycle-time, reduce time spent in the MAT queue, and potentially increase throughput.

The information used to formulate the simulation models was obtained from Company B, MCCES, located in Twentynine Palms, California. The focus is on the seven, entry-level MOSs taught by that command.

F. STRUCTURE OF THE THESIS

The thesis is divided into seven chapters. Chapter I provides a brief introduction including research questions, project scope, and summarized methodology. Chapter II describes Company B and MCCES backgrounds, MCCES command structure, and briefly summarizes MOS course specifics. Chapter III is a literature review summarizing academic research and documents relevant to improving organizational processes. Chapter IV describes the MCCES training process, explains physical and policy constraints, and explains the general operation of the simulation model. Chapter V explains the design of the experiment, the validity of the model and its design parameters, and discusses the results. Chapter VI illustrates the cost benefits of implementing improvements to the system to include statistical improvements, potential cost reductions, and opportunity cost considerations. Chapter VII summarizes the researcher's conclusions and recommendations, and the recommended areas for further action and research.

II. MARINE CORPS COMMUNICATIONS-ELECTRONIC SCHOOL

A. MCCES BACKGROUND[2]

The Marine Corps Communication-Electronics School began as the Pigeon and Flag Handler Platoon in 1932. In 1942, the Marine Corps activated the Signal School, Signal Battalion, at Quantico, Virginia. The next year, the school was relocated to Camp Lejeune, North Carolina where it eventually offered 15 different communications field courses. The school remained at Camp Lejeune throughout World War II. In 1946, the school was moved to Camp Pendleton, California, where it continued to train vital communications Marines in lower numbers than during WWII. In 1949 the school was re-designated as the Signal and Tracked Vehicle School Battalion.

The outbreak of the Korean War prompted the newly named school to relocate to the Marine Corps Recruit Depot in San Diego, California in 1950 to accommodate the expansion required to train increased numbers of communications personnel to support the war. In 1953, the school was yet again re-designated as Communication-Electronics School Battalion. Beginning in 1967, the school began its move to its present location in Twentynine Palms, California, when Company C and Company E relocated followed by Company A and Company D in 1971. Also in 1971, the school was re-designated to its current title of Marine Corps Communication-Electronics School.

During the Vietnam conflict, the school surged to train over 5,000 Marines annually and became the formal school to train officers in air defense and support. In 1975 Company B, the largest of the companies at MCCES, completed its move to Twentynine Palms. With Company B on deck, MCCES became the largest formal school in the Marine Corps. In 2003, Company D, Computer Sciences School, merged

[2] C. Craven, personnel communication, June 8, 2007.

with Company B, making Company B the largest company in the Marine Corps, comprised of approximately 120 permanent personnel and 500-1,200 Marine students.[3]

MCCES is the training location for the second largest occupational field (06XX) in the U.S. Marine Corps. Their importance has grown as the Marine Corps continues to increase their reliance on technology as an integral part of their warfighting capability and leverages technology as a force multiplier. Further, with current Marine Corps end strength increasing from 180,000 (Scully, 2006) to 202,000 (Grant, 2007) over the next five years beginning in 2007, the importance of MCCES in achieving the Marine Corps mission will also grow.

B. CURRENT OPERATIONS

MCCES' mission is:

> To train Marines in communication-electronics maintenance, operational communications, air control/anti-air warfare operations, computer programming/networking and to participate in the doctrine, organization, training, material, leadership and education, personnel, and facilities (DOTMLPF) process as the command, control, computers, and communication (C4) Training and Education Center of Excellence (TECOE) for new communications electronics systems training development (Background, MCCES, retrieved August 4, 2007).

To accomplish this mission, MCCES provided 56 formal courses during 2006, 51 of which were resident and five of which were conducted via Mobile Training Teams (MTT), which produced 35 different MOSs. That same year, MCCES conducted 397 classes differing in duration from 17 to 168 training days. MCCES graduated 4792 Marines, 2895 of which were Company B Marines.

C. ORGANIZATIONAL STRUCTURE

MCCES is a subordinate command of Marine Corps Training Command. However, it receives direction from and liaises with other commands not directly in its

[3] Size is based upon permanent personnel and student population at Company B.

chain of command. Figure 1 displays the organizational relationships. As an example, MCCES receives direction and support from Command, Control, Computers, and Communications (C4). MCCES also communicates with Marine Corps Combat Training (MCT) battalions East and West. This relationship, although informal, allows MCCES to be more responsive to the needs of the Marine Corps by helping MCCES adequately prepare for arriving Marines as they complete their initial training and arrive for primary MOS training.

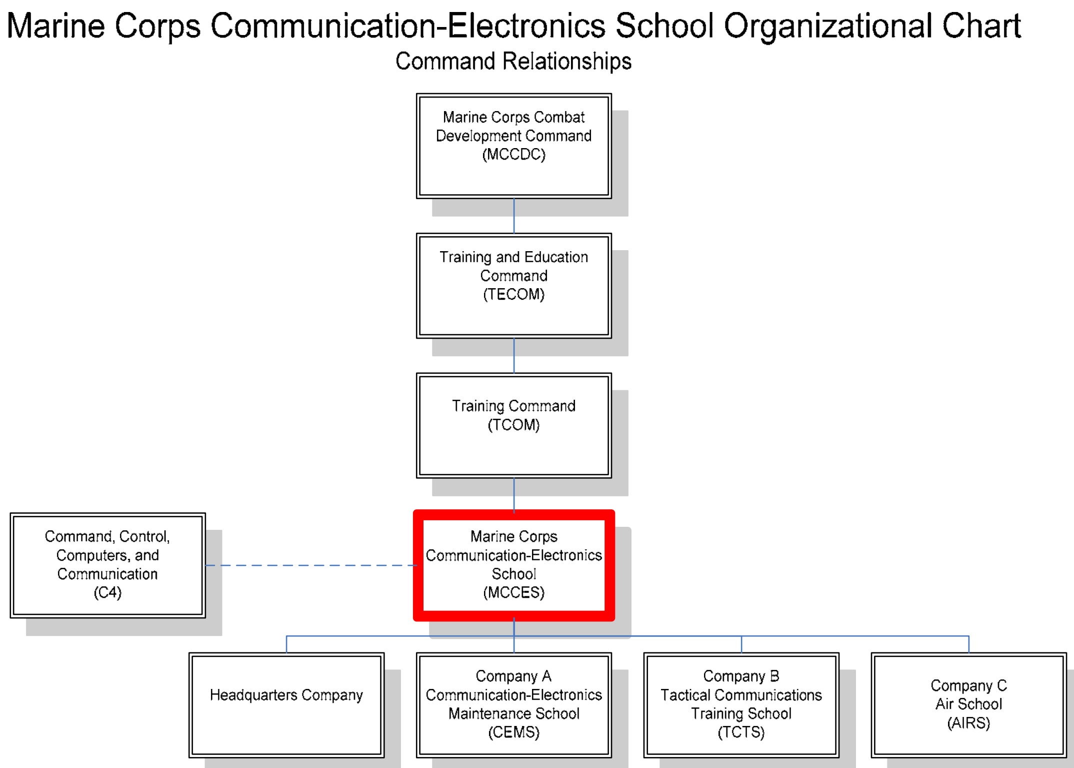

Figure 1. MCCES Organizational Chart and Chain of Command.

D. MARINE OCCUPATIONAL SPECIALTY (MOS) DESCRIPTIONS[4]

Field Wiremen (MOS 0612) are the foundation of wire communications in the MOS manual. Personnel holding this designation construct, operate, and maintain wire

[4] MOS descriptions are found in each training course's Program of Instruction provided by MCCES.

networks to link key outposts, control points, and headquarters with reliable paths for the transmission of voice and data messages. Typical duties of this MOS are installing telephones and switchboards, laying wire and cable, adjusting equipment for proper operation, recovering wire, locating wire system faults, and operating switchboards. This entry level MOS is normally made up of the grades Private (Pvt) through Lance Corporal (LCpl).

Unit-level Circuit Switch Operator and Maintainer Course (MOS 0614) provides technical instruction pertaining to the operations and performance of organizational maintenance on the Central Office AN/TTC-42. Instruction is provided on installing and interconnecting equipment, performing limited technical control of the voice/data network, and updating the database or crypto keys to ensure reliable, secure telephone service for the user. This course also includes instruction on equipment characteristics of MOS related COMSEC devices and fault isolation procedures for tactical communications systems links. This entry level MOS is normally made up of the grades Private through Lance Corporal.

Field Radio Operators (MOS 0621) employ radios to send and receive messages. Typical duties include: the setup and tuning of radio equipment, including antennas and power sources; establishing contact with distant stations; processing and logging messages; making changes to frequencies or cryptographic codes; and maintaining equipment at the first echelon.

Mobile Multi-channel Equipment Operators (MOS 0622) install, operate, and maintain at the first echelon, multi-channel communication equipment. The equipment currently is use is the AN/MRC-142.

Transportable Multi-channel Equipment Operators (MOS 0623) install, operate, and maintain at the first echelon, multi-channel media equipment. The equipment currently in use is the AN/TRC-170(V)3.

Tactical Data Systems Operators (MOS 0651) study small computer systems. Topics covered include: The installation and configuration of Marine Corps hardware and Marine Corps authorized common suite operating system software; installation and configuration of workstation and server operating systems; installation and configuration of messaging systems; installation, operation and maintenance of Local Area Networks (LAN) and equipment, trouble-shooting techniques, and information assurance.

Tactical Data Network Operators (MOS 0656) are responsible for installation, configuration, operation and maintenance of networking systems. This includes installing and configuring switches, routers and various transmission media. Tactical Data Network operators also install, optimize and trouble-shoot Wide Area Networks and operate the current Tactical Network System. They will receive core data concepts training before receiving more detailed training in tactical networking principles and systems. This MOS will be assigned and voided only by the authority of the Commandant of the Marine Corps (CMC).

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III. LITERATURE REVIEW

A. INTRODUCTION

This chapter reviews articles and concepts relevant to improving organizational processes, including theoretical foundations applicable to the Marine Corps Communications-Electronics School (MCCES). Attempting to balance both scope and depth of a considerable body of organizational process strategies, tools and approaches, the following topics are discussed: Continuous Improvement, Lean, the Bullwhip Effect, Drum-Buffer-Rope, Little's Law and Queuing Theory, Systems Thinking and Resource Constraints, Activity-based Costing, Time-based Costing, and an overview of modeling and simulation.

The improvement of typically complex business processes includes using an array of rational tools, methods, and approaches. This chapter incorporates these concepts as precursors and foundations needed to address the topic of improving the MCCES queuing system.

B. CONTINUOUS IMPROVEMENT (CI) AND THE THEORY OF CONSTRAINTS (TOC)

It is generally acknowledged that Continuous Improvement (CI), or Kaizen in Japanese, is practiced in some way, shape, or form by most if not all Fortune 500 companies. It is an overarching philosophy and practice of incrementally improving every aspect of the business using scientific methods and statistical process controls (Baghel & Bhuiyan, 2005). Continually improving what your business is already doing makes logical sense, unless the environment demands vastly new products or services outside your traditional process.

Baghel and Bhuiyan (2005, p. 761) define CI as, "A culture of sustained improvement targeting the elimination of waste in all systems and processes of an organization. It involves everyone working together to make improvements without necessarily making huge capital investments." Working together in harmony closely fits the collectivist Japanese culture, but may face greater resistance in the individualistic U.S. culture. Kaizen generally involves methodical examination and testing, followed by the adoption of new or streamlined procedures, including scrupulous measurement and changes based on statistical deviation formulas. Kaizen appears to be a perfect fit for repetitive manufacturing and production operations where comparative evaluations of data are possible. With the development of complex modeling and simulation software, Kaizen recommendations can now be tested prior to implementation, resulting in the reduced investment of resources.

The Department of Defense (DoD) understands the importance of CI. For example, this theory is an integral part of the U.S. Navy's Naval Enterprise concept. In a speech to the employees of Pearl Harbor Naval Shipyard, Vice Admiral Paul Sullivan, Commander Naval Sea Systems Command (NAVSEA) said, "You need to keep working on Continuous Improvement" (Fukiki, 2007, p. 1). Vice Admiral Sullivan then outlined his top five areas of focus, one of which is, "Document and improve our processes through Lean/Six Sigma. Continuous Improvement using Lean/Six Sigma provides a means to reduce maintenance costs" (Fukiki, 2007, p. 1). As another example, Lean as a component of CI, will be used by The Boeing Company and Lockheed Martin Corporation in the development of the Joint Strike Fighter (Adams, 2002). Additionally, former Commandant of the Marine Corps, General Charles Krulak, implemented the overarching Marine Corps Continuous Improvement Program (CIP). The ongoing program attempts to make the Marine Corps a more process-centered organization and to catalyze movement away from crisis management. The CIP, in its effort to improve performance and efficiency, calls for the disintegration of organizational and cultural barriers (Freedman, 1997). It is important to note that there are obstacles, bottlenecks, and impediments to building a CI culture in organizations substantially affected by public authority, e.g., defense organizations, agencies and bureaus (Backoff & Nutt, 1995). It is for this reason that the researchers structured their focus using the theory of Continuous Improvement, i.e., bottlenecks were identified and removed. Recommendations were constructed utilizing this idea and improvements were modeled to prove their validity as well as to prove that they could be realistically implemented.

Eliyhau Goldratt's Theory of Constraints (TOC) proposes that in any multi-stage processing system, one stage will be slower than the others (McMullen, 1998). As such, TOC is a management science. It is based upon physics concepts and is used to determine cause-and-effect relationships to find the minimum number of adjustments and the simplest solutions to improve upon the constraints of a system. In this way, it can increase throughput while decreasing inventory and operational costs (McMullen, 1998). TOC capitalizes on the concept of the critical chain (CC) of a processing system. A critical chain spotlights the importance of timely delivery, as opposed to the achievement of individual tasks or milestones within a processing system ("Critical chain basics," 2007).

1. Principles of Employing TOC

TOC in operations is facilitated by following the five systematic steps designed to reduce the effect of the critical chain in a processing system:

1. Identify the system's constraint(s).
    a. What is causing the problem? Is it a physical or a policy constraint?
    b. Improving physical and policy constraints requires different courses of action.
2. Decide how to exploit the system's constraint(s).
    a. If it is a physical constraint, can all the processes in the system be benchmarked against the constraint?
    b. If it is a policy constraint, can the policy be eliminated or altered to negate the effects of the constraint on the system?
3. Subordinate everything else to the above decisions.
    a. If it is a physical constraint, ensure all processes are adjusted in relation to the constraint.
    b. If it is a policy constraint, current policy should change to align policy and objectives with the identified system constraint. Policy makers must take the constraint into consideration before adopting future policy decisions.
4. Elevate the constraint(s).
    a. The constraint becomes the focus of effort. All actions should be taken to get the most out of the constraint.

5. When the constraint is overcome, return to step 1.
    a. The process is continuous. When the constraint is no longer binding, begin the process again. (Goldratt, 1997)

Applying the five steps of TOC can reduce the effects of a constraint by guiding the manager to continually evaluate the system (Step 5) to determine bottlenecks (Step 1), and to synchronize the system to that constraint (Step 3). Bottlenecks may never be completely removed, e.g., there may always be a system bottleneck that will shift within the system. TOC reflects CI and Kaizen principles. When employing TOC tactics to improve performance, anticipating new bottlenecks is reinforced, i.e., look beyond marginal improvement and attempt to innovate when considering system improvement.

McMullen (1998) states there are two categories defining the characteristics of constraints: physical constraints and policy constraints. A physical constraint is anything that is measurable. Physical constraints may be time, space, capital, material, demand, supply, or other resources. In contrast, a policy constraint in and of itself is not measurable. Policy constraints are generally those that derive from all other sources, such as organizational culture, work ethic, willingness to accept risk, and standard operating procedures (SOPs).

Identifying the constraints as either physical or policy-oriented allows one to determine the appropriate approach to refine the system. For example, if a manufacturing company has an SOP mandating all resources perform at a 90% efficiency rate, it is possible to have excess inventories accumulate at various stations along the production route if each stage of production takes a different amount of time. In this case, the problem of excess inventories stems not necessarily from a physical constraint, such as a lack of resources to process inventories or a lack of time, but rather from a self-imposed policy constraint of arbitrary efficiency ratings. The Theory of Constraints proposes that the rate of revenue generation is limited by at least one process (Goldratt & Cox, 1992). Ways around resource-constrained processes that are limiting a system from reaching its goal are to assign more labor, work overtime, or modify policies to increase the output of the system.

Goldratt (1997) states that managers are normally focused on controlling costs and/or protecting throughput. Further, he states that a manager's focus on costs can lead to diminished quality or service, while a focus on throughput can actually increase costs (Goldratt, 1997). The central idea is that management's focus should be balanced between the competing priorities of cost and throughput.

It is important to note that costs at MCCES include not only the costs of training Marines in terms of materials, facilities, and salaries of both the students and the instructors, but also the opportunity cost of failing to deliver trained Marines to the operating forces in a timely manner. Because MCCES does not generate any revenue from either the service or the product, the fiscal costs and opportunity costs associated with waiting for classes to begin are often overlooked. In fact, historical data provided by MCCES shows that annual operating budgets have generally stayed the same or increased over the last five years.

MCCES generally focuses on throughput; moving Marines through the training continuum in an expeditious amount of time. Unlike typical production in the manufacturing industry, MCCES' product of 06XX Marines differs from what Goldratt (1997) terms the "end of the month syndrome." Rather than focusing on costs at the beginning of a particular cycle, be it a fiscal cycle or a production cycle, and then focusing on throughput at the end of a cycle, MCCES generally focuses on throughput through the entire cycle, while cost is generally a secondary concern.

C. LEAN

One of the principles of CI is the idea of *muda*, the Japanese term for waste, and the process of its systematic elimination. Waste can be categorized in terms of wasted time, excess inventory, unnecessary individual effort, and wasted space. Efforts to remove *muda* are intended to improve human factors, productivity, and the bottom line process. Jones, Miller, and Srinivasan (2004) note that Lean Thinking and Theory of Constraints (TOC) result in increased morale in the work space and that, "The workplace is cleaner, less cluttered, and safer" (p. 143). By eliminating *muda*, an organization may be able to reduce costs and lower their prices, thereby strengthening their competitive advantage. The idea is that customers should not be forced to pay for waste nor should employees suffer the burden of unnecessary or extraneous work processes.

One of the foundations of Lean is that inventory can be considered waste, i.e., stored inventory incurs associated costs. Production firms are also learning that storing inventory is often unnecessary, even with variations in demand. Therefore, the compelling logic is that *storing* Marines awaiting classes at MCCES incurs associated costs, the crucial one being a possible degradation in operational readiness. One important aspect of attempting to reduce inventory is the reduction in cumulative lead time. Shields (2006) illustrated three viable benefits of that pursuit: smaller lot sizes, decreased importance of demand-forecast accuracy, and improved customer service levels. Although this study is not about manufacturing or production process improvement, the application of CI and Lean processes should also apply to administrative functions such as scheduling, which can account for 60 to 80% of required lead time. The *muda* created by a scheduling process can be eliminated by a Lean process as part of evaluating the value stream to customers ("The new improvement frontier," 2005).

Implementing major change (including acknowledging that major change is needed) may be closely related to the concept of organizational learning (Senge, 2006). Toyota acknowledged that its *Toyopet* car in 1961 was too small, underpowered and stodgy, yet it learned with its Corona model to produce a car that fit America's roads and consumers. Organizational learning and culture can generate complex interrelationships. Freedman (1997, p. 64) indicates that organizational change requires dedication from the entire organization, and, "The challenge that confronts individuals and organizations is to create a climate for effective change on a continuing basis."

D. BULLWHIP EFFECT

The Bullwhip Effect can be described as the variability in demand throughout the supply chain while end-use (consumer) consumption remains constant. According to Lee, Padmanabhan, and Whang (1997), the symptoms of the Bullwhip Effect are, "excessive inventory, poor product forecasts, insufficient or excessive capacities, poor customer service due to unavailable products or long backlogs, uncertain production planning (i.e., excessive revisions), and high costs for corrections" (1997, p. 93). This is another concept, originally developed to explain situations encountered in material supply chains, which can be applied to the process of training Marines.

An example used to teach the Bullwhip Effect is the Beer Game. The Beer Game is an exercise in which students are arranged to simulate the supply chain of a beer company including the retailer, wholesaler, distributor, and factory. The game closely simulates reality as it incorporates transportation lead-times, product lead-times, and order processing delays. Material flows down the chain, and information flows up the chain; however, the different "actors" are not allowed to speak nor are they allowed to share information. The proctor for the exercise hands the student (retailer) very similar demand requirements (identically distributed random variables) during each game period. However, beginning with the retailer and proceeding up the chain, each actor adds safety stock attempting to compensate for the various delays in the supply chain. The formula for ordering is on-hand inventory minus backorders plus outstanding orders. By the time this information reaches the manufacturer, it feels forced to produce extra amounts of product to respond to the perceived demand, which is held constant during the exercise. This result is described by Chen and Samroengraja (2000) as the variance amplification phenomenon, in which, "upstream orders tend to be more volatile than the downstream ones," (2000, p. 20) as a result of players failing to make rational decisions.

The Marine Corps *consumes* communication trainees (06XX MOS) at a steady rate. They are distributed among the following: Delayed Entry Program (DEP), Marine Corps Recruit Depot (MCRD), Marine Combat Training (MCT) Battalion, MOS schools, the Operating Forces, or are in the process of separating. The distribution and process of training 06XX Marines at MCCES relies upon effective communications from policy makers who determine both when classes are scheduled and the number of 06XX Marines that are sent to MCCES. While Headquarters Marine Corps (HQMC) may provide an accurate quota to MCCES to fill its demand for 06XX Marines, and the schedule Company B develops may meet the quota from HQMC, the variability in arrival rates of students due to seasonal input variances at the Recruit Depots results in some scheduled classes being canceled due to the inability to meet minimum class-size standards at Company B MCCES (which are in place to maximize efficiency), and some classes exceeding the maximum class size. Further, long waiting queues form when arriving Marines exceed Company B capacity. This can result in MCCES requesting more scheduled classes in order to reduce the inventory of MAT, but requests are based on what MCCES perceives as an accurate demand trend and not on the actual rate of "consumption." The communication between MCRD, MCT, and MCCES therefore becomes crucial to MCCES' responsiveness to arrivals, and resultantly, the minimization of the Bullwhip Effect.

There is tremendous value in effective communications, or information sharing, between end-users (Operating Forces) and manufacturers (MCRD, MCT, and MCCES). If these entities succeed in effectively communicating, they can mitigate the effects of the Bullwhip. Effective communication between Marine Corps Recruiting Command (MCRC) and HQMC may also eliminate some of the Bullwhip Effect, but the responsiveness of MCCES and its ability to efficiently process Marines will eliminate the remainder.

E. DRUM-BUFFER-ROPE

The Drum-Buffer-Rope (DBR) concept is a method employed to manage system constraints by regulating the flow of jobs through a system to the capacity of the slowest resource in the system. The "drum" can be described in terms of the exploitation phase. The exploitation phase is using the constrained resource in relation to the system to improve upon or optimize production. That is to say, the drum sets the tempo for the entire system. The drum ensures that all operations within a system are operating at the same overall pace. The buffer is protection time designed to ensure that the bottleneck or capacity constrained resource (CCR) does not starve during a disruption upstream. The buffer should be sized to match the amount of fluctuations and capacity of non-constrained processes or resources in the system. The buffer ensures that there is no lost time on the constrained resource should disruptions occur upstream. The rope is the overall schedule for releasing jobs into the system; at MCCES, the rope could be considered the current use of schedule classes. The rope is a regulatory device that ensures that material is released when a process requires it in an attempt not to constrict process flow. Once time is lost on a constrained resource due to starvation or downtime, it is lost forever. (Ronen & Schragenheim, 1989). At MCCES this loss of time on a constrained resource occurs when a scheduled class is cancelled.

F. LITTLE'S LAW AND QUEUING THEORY

Little's Law is named after John D. C. Little who was a professor of management science at the Sloan School of Management at the Massachusetts Institute of Technology. What makes this law special is that one can determine how long on average it will take to complete the work tasks in a particular process from just two other pieces of information: the throughput rate of the system and the number of work tasks in the system. Conversely, if the average time in the system, as well as the throughput rate, is known, the number of work tasks in the system can be calculated. Gerst points out that, "Little's Law is now a fundamental part of queuing theory and has found broad application in the design of computing systems, customer service functions, and logistics" (Gerst, 2004, p. 18). Little's Law is based on the equation WIP=TH x CT, where TH (throughput) equals the arrival rate, CT (cycle-time) equals cycle-time, or average time spent in the system, and WIP (work in progress) equals the average number of units in the system. Throughput is determined by dividing the number of items produced by the length of time it took to make them. The idea of "Lean" is based on the assumption that Little's Law works (Gerst, 2004).

While actual throughput of MCCES is limited by the quantity of Marines sent there for training, Little's Law has implications affecting the internal process at MCCES. If for example, the theoretical cycle-time for a particular MOS at MCCES is determined to be three units (Marines) each day, as long as Marines destined for training in that MOS arrive at a rate no greater than three per day the system will remain in balance. However, because training is not conducted continuously, that is to say training for a particular MOS only begins on dates determined arbitrarily by MCCES and HQMC, WIP will increase, i.e., the number of Marines in the MAT platoon will increase. This is a direct implication of Little's Law; as units (Marines) arrive, production efficiency will decrease if the units do not immediately begin the training process. That is to say, the average cycle-time will increase as a direct result of the increase of WIP assuming TH remains constant. Conversely, if the system has excess capacity, increasing inventory will result in the flow rate increasing proportionally; however, cycle-time will remain unchanged because the length of each MOS course is pre-determined (Bandy & Godfrey, 2005).

To decrease cycle-time there are two options dictated by Little's Law: Increase throughput or reduce WIP. Both of these options were examined and incorporated into the models for analysis. Reducing WIP and increasing throughput at MCCES may have substantial implications for the Marine Corps' mission. Measuring cycle-time using Little's Law also appears crucial to cost analysis of potential improvements to the MCCES system. Gerst (2004, p.19) makes the point when he states, "When looking at the larger system, including the costs associated with holding inventories, the total cost of production tends to rise with large production volumes." This statement has particular relevance to MCCES as the Marine Corps' end strength increases.

The subtle difference between Little's Law and TOC is best explained by Bandy and Godfrey when they state, "Little's Law generally is best understood when it is used to reduce cycle-times (flow times), while TOC leads quickly to being able to identify and elevate a physical constraint (bottleneck) to increase throughput (flow rates)" (Bandy et al., 2005, p. 37).

G. SYSTEMS THINKING AND RESOURCE CONSTRAINTS

Systems are inter-related parts working towards a common purpose (Heylighen, 1998). Systems thinking suggests that system components act differently when isolated from their environments or other parts of the system. The interaction between the system and the environment includes input and output variables. Because the whole is greater than the sum of its parts, the relationship between the parts and their interaction with the environment is what should be under observation (Senge, 1990). This type of analysis is especially relevant to MCCES as they are in intermediate step in the process of delivering Marines to the Operating Forces.

Systems with resource constraints challenge one to become more creative in order to solve problems in contrast to a traditional method of adding more resources at a problem to make it work faster (Gibbert, 2007). Because of high turn-over rates of personnel in the military as a whole, many commands attempt to overcome resource constraints by purchasing more resources to improve efficiency. This procedure can solve problems in the short run, but if the system is not improved (i.e. remove bottlenecks to improve throughput), then those resources will be delayed at the system bottlenecks. Too often, resource constraints are seen as inhibiting effects, and decision-makers rely on increasing resources with the hope of generating some intuitive outcome without knowing which resource is the scarce one. Possible outcomes from the resource-driven mindset are an over-reliance on resources (instead of allowing for resource parsimony) or a deployment of the least resources necessary to achieve the desired results. It makes sense that it takes more than just resources to achieve success or accomplish a goal. Innovation will continue to improve current processes and systems, making them more efficient and using fewer resources (Gibbert, Hoegl, & Välikangas, 2007). In order to innovate and overcome constraints, would-be efficient solutions are often not given an opportunity because of the inability to examine the system as a whole.

Resource constraints can fuel innovation in at least two ways. They can lead to entrepreneurial approaches to securing required resources using social networks instead of economic strategies, and they can fuel innovative team performance supporting the phrase, “necessity is the mother of all invention” (Gibbert et al., 2007). When one’s thinking parameters are restricted, one may focus better on constraints, i.e., increased ability to find innovative solutions and unexpected ideas. Obviously, multiple resources are often needed to achieve success or accomplish goals. The idea is that innovation can improve current processes and systems, including making them more efficient (Gibbert et al., 2007). Innovation can occur in many and multiple arenas including: leadership, communication, organization, knowledge management, and technology advances (Gibbert et al., 2007, p. 16)

A resource-driven mindset can create a reinforcing loop, where small change builds upon itself (Senge, 2006). In some cause-and-effect relationships, adding resources can fuel success or failure and can be blamed on inadequate time or available resources (Gibbert et al., 2007). The resulting logic can be that the workforce needs to put more in to get more out. This concept is not relevant at MCCES because, for example, no matter how hard MCCES instructors work, they will not reduce the quantity of Marines in MAT without a corresponding policy change in the scheduling of classes. Sometimes, cause and effect relationships are subtle, and the changes are not obvious in the short run. Dynamic breakthroughs are sometimes missed because managers apply tools that are far too complex in order to identify system limits and constraints. By managing and scheduling the constrained resources and their quantities, models can help predict the minimum required resources to meet specific goals (Senge, 1990). Managers sometimes fail because the methods they employ are designed to provide solutions to short-term problems. But, when the same action has both long-term and short-term effects, there is dynamic complexity (Senge, 1990). In order to overcome dynamic complexity, or rather benefit from it, organizations must be willing to permit dynamic change that may lead to actions which result in cost savings and increases in the rate of production in the system.

Resource constraints exist in virtually all systems, and are not necessarily negative in nature, i.e., nature is equilibrium-seeking. Managing scarce resources is obviously meant to balance both costs and performance. There are many ways to examine constrained resources and calculate what required resources are needed to create innovative balancing solutions. Too often, the less complicated and more costly choice of adding resources to increase production may fail to meet organizational goals (Gibbert et al., 2007). Resource constraints are perhaps inherent in every process because they can define capacity-critical processes and needed inventory critical to efficient management. Resource constraints may also encourage thinkers to consider innovative solutions to detailed and dynamic problems.

Systems and processes are of course modified and refined over time. Additional methods to improve production and develop innovative ideas include:

1. Balancing processes (Goldratt & Cox, 1992).
2. Managing delays that interrupt balancing actions (Senge, 1990).
3. Inviting outside experts (Janis, I., 1983).
4. Looking for alternate sources to scarce resources from social networks (Gibbert et. al., 2007).
5. Sharing information to improve the performance of the resource allocation in the system throughout the supply chain.

The premise is that since a minimum amount of resources are required to accomplish a given goal, simply eliminating all resource constraints may not result in unlimited innovation. Understanding the relationship between the organizational system and its environment may induce managers to rethink cause-and-effect relationships, which may not be close together in time and space.

H. ACTIVITY-BASED COSTING (ABC)

Activity-based Costing (ABC) is a method of allocating costs to products or services. It is especially relevant to the examination of the training process at MCCES because this method first assigns costs to activities and then to products or services based on the product or service and usage of the activity. It is generally used as a tool for planning and control, but it is also used as a value-chain analysis tool. ABC was derived from traditional accounting methods as a more accurate method of assigning overhead costs due to indirect costs not being equally spread across all products. Instead of using percentages that can either overestimate or underestimate allocated costs, ABC attempts to establish a cause-and-effect relationship between activities and indirect costs. In this way, ABC can identify relationships of high fixed costs based on utilization of these activities per unit in order to find ways to reduce costs or to charge more for costly products (Cooper & Kaplan, 1992,).

There are five steps in designing an ABC accounting system:

1. Analysis of activities: identify individual activity pools.
2. Cost data gathering: determine costs to be included by activities.
3. Tracing cost of activities: determine source of total costs of each output.

4. Establishment of output metrics: identify cost drivers and trace costs to activity centers to determine the total cost of production per unit.
5. Cost analysis: compare unit costs to activity costs to identify areas for future improvement. (Cooper et. al., 1992, p. 43)

An activity's cost allocations are made by identifying cost drivers; valid cost drivers are causally related to the associated activity cost pool of a particular product. Two major advantages can result from this method. First, because all costs are allocated to a specific pool, causal relationships can be attributed to cost drivers. Second, by identifying activities, costs that relate more or less to production can be applied. One of the challenges, and a major problem with ABC, is designing an ABC system that supports these requirements (Fritzsch, 1997).

ABC assumes that all costs can be traced to the product or service and that they will vary in proportion to applicable cost drivers. ABC has been described to be an appropriate method to aid decision-making in all situations. ABC has limitations in the use of cost data for short-run analysis due to the difficulty in obtaining accurate application of the mostly fixed or sunk costs applicable to those decisions (such as the size of the plant and production capacity that cannot be changed in the short run), and it is unable to identify bottlenecked resources. ABC is applicable in cost-analysis decisions, but it is most powerful for product and service cost analysis in the long run, when all costs are variable (Cooper & Slagmulder, 1999).

When products have the same production process, they are referred to as "joint products." Joint products are generated in a joint process before they are further processed in separate methods. ABC is a flexible tool that can be used to trace product costs and/or process costs. If a condition of having identical product costs exists in the joint process, attributing costs in a situation where the processes were separated could only be traced later in the process and with in-depth value-added analysis. This method describes the cost-assignment view of ABC, in which financial and non-financial data provides information about resources, activities, and cost drivers. Because joint products are produced in a joint process, product-cost determination should be traced eventually to processes, then to products. Lai and Tseng (2007) describe the ABC process as being composed of three building blocks:

1. Cost drivers, workload and effort.
2. Activities (why activities are performed via cost drivers).
3. Performance measures (how well the activities performed). (p. 237)

In reference to performance measures, there are five fundamental elements of performance:

1. Quality of the work.
2. Productivity of the activity.
3. Cycle-time required.
4. Cost traced or allocated to the activity.
5. Customer satisfaction. (p. 239)

ABC provides more accurate real-cost computations and allows deeper analysis of product cost determination based on performance measures and cost drivers. One of the special features of ABC is that it can be product- or process-based and volume-based (volume-based by unit or non-volume-based by batch level, product level, or facility level) (Fritzsch, 1997). The cost detail in ABC allows overhead and process costs to be analyzed in order to support future decisions in product choice, production capacity, or other Lean methods. Fritzsch (1997) shows the situations when one should use ABC or TOC costing methods in Figure 2 (p. 88). This graphic shows the relationship between very short-run and very long-run decisions and the methods that can be used to affect each (Theory of Constraints and Activity-based Costing).

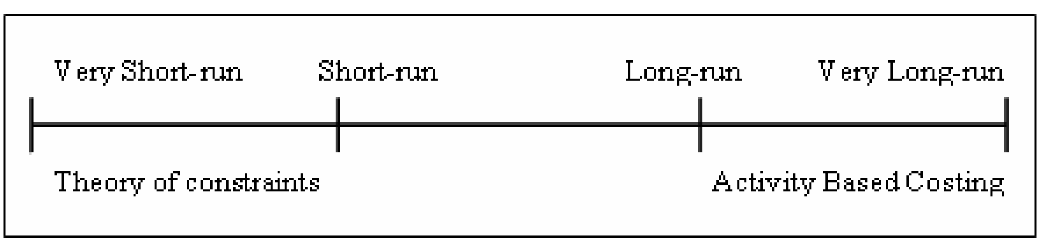

Figure 2. Decision Time.

I. TIME-BASED COSTING

Traditional and modern methods of cost accounting are very good at identifying the cost of a product or service. A more accurate way to phrase the question of costs may be: "How much is the rate of costs, or outflow of money, changed by the sale of one unit of product?" (Preiss, 2000, p. 68).[5] Differences in time and resource consumption by products differ; therefore, so do costs and profits. The rate of resource consumption may be non-linear, i.e., a doubling in time may triple the resource consumption. Or, in other cases where speed is increased, the resource used may experience a bottleneck which may further increase costs. If the unit of time is not considered when unit costs are computed, then the computed costs will not match actual costs. Decisions that flow from the data without the consideration of time will likely be faulty.

In cases where inflows and outflows of money are constant, traditional costing methods identify the most profitable mix and production quantities for goods and services per unit of time. Goods and services that produce the largest margin per unit also give the best margin per unit-time (Preiss, 2000). But, when money or product flows are seasonal or follow variable trends, the effect of time will have an impact on the costs of the products that take longer to produce than others. With the objective function either to maximize profits or minimize costs, knowing which products or services most benefit the organization per unit of time will lead to better production decisions and allocation of scarce resources. When the resource or income flow is dynamic, the product having the best margin per unit of time will result in having the best outflow of products to customers (Preiss, 2000).

J. OVERVIEW OF MODELING AND SIMULATION

Kelton, Sadowski, and Sturrock (2004) define simulation as, "a broad collection of methods and applications to mimic the behavior of real systems, usually on a computer with appropriate software" (p. 3). They go on to explain that models are a tool used to

[5] At MCCES, the relevant measure is how much it would cost to train one additional Marine.

analyze a particular system and form the basis of simulation. That is to say, models describe a process and allow users to understand the behavior of a particular system.

With the advance in the processing power of personal computers and lower costs of applications, simulation and modeling have become cost-effective methods to improve upon current procedures or recognize the need to innovate new ones. The benefits of using software to analyze changes to current procedures are far reaching. They include the ability to statistically analyze changes to current operations without actually changing them and the ability to look at the effects of simultaneous changes. In fact, the author of *Model Performance* stated that, "Many manufacturers have been able to use the Arena [modeling software] package to demonstrate that planned expenditures were unnecessary: the required improvements in throughput and efficiency had been hidden in undiscovered bottlenecks and wasteful processes" (2003, p. 36). Simply, simulation and modeling software allows users to measure performance of resources and processes in a non-obtrusive manner.

There are general guidelines and procedures that are followed when designing a simulation and modeling experiment. The steps valid for this particular study are:

1. Have an intimate knowledge of how the system that is being modeled works.
2. Set clear and well-defined goals.
3. Formulate the model representation.
4. Translate into modeling software.
5. Verify the computer representation accurately represents the conceptual model.
6. Validate the model.
7. Design the experiments.
8. Run the experiments.
9. Analyze results. (Kelton et al., 2004)

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IV. MCCES PROCESS DESCRIPTION AND THE SIMULATION MODEL

A. OVERVIEW

Company B, MCCES trains seven MOSs, each having varying length, minimum/maximum class size, and varying annual arrivals, as shown in Table 1. The throughput over a given period of time is limited by the number of students sent to MCCES to complete that MOS training—assuming that the system is able to process each student. That is to say, because incoming raw material (student Marines) are controlled by higher authority, the maximum graduates per MOS are limited to the quantity sent to MCCES for training.

MOS	Normal Length (days)	Min Class Size	Max Class Size	Annual Arrivals (FY2006)
0612	17	14	20	397
0614	40	5	10	100
0621	30	20	45	1173
0622	30	20	27	132
0623	31	10	13	34
0651	40	15	30	267
0656	41	15	20	421

Table 1. Listing by MOS of Class Length, Minimum and Maximum Class Size, and FY2006 Arrivals.[6]

B. TRAINING PROCESS DESCRIPTION

Working from fiscal year (FY) 2006 (Oct. 1-Sept. 30) data, there were 49 weeks in which MOS 06XX Marine students arrived at MCCES—roughly once every seven days excluding holidays. Three weeks of the year no student Marines arrive due to inactivity during the Christmas holiday routine.

Upon arrival, the students spend three days in an indoctrination course before being transferred to the Marines Awaiting Training (MAT) Platoon where they wait until a scheduled class begins. When a scheduled class start-date arrives, the class can commence provided that the minimum number of students per class criteria is met. If there is an insufficient number of Marines to begin a class, the class is cancelled. If there are more Marines than the maximum capacity of the class, only the maximum number will begin the scheduled class. The remaining Marines must then wait for the next scheduled class to start. Marines are processed on a First-in First-out (FIFO) basis. Each course consists of lecture and practical application. Some courses also include a laboratory period of instruction. For illustrative purposes, the basic process flow for an MOS with a laboratory requirement is depicted in Figure 3. For MOSs where there is no laboratory requirement, the "Educate (Laboratory)" step is not included in the model. Upon completion of the course, Marines graduate and depart the school.

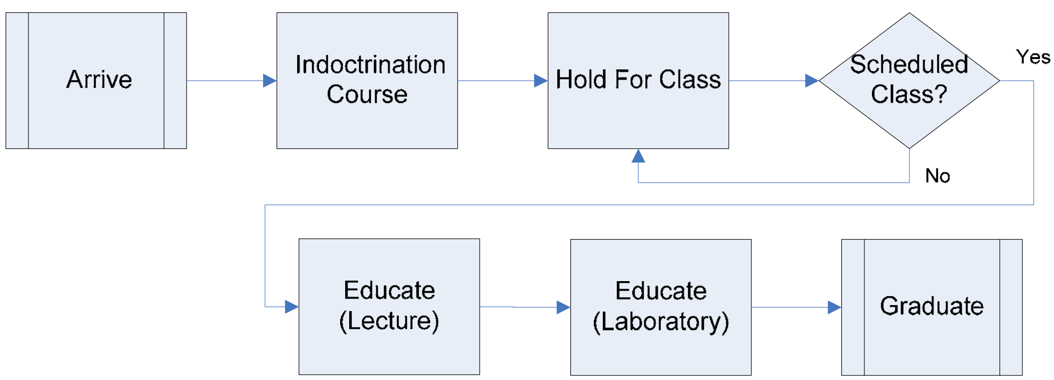

Figure 3. Student Flow through MCCES.

Training days are exclusive of weekends and holidays. The Course Descriptive Data (CDD) for each course specifies a minimum and maximum class size. The maximum class size is determined by several factors including the physical capacity of

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[6] Information in Table 1 is derived from the Course Descriptive Data, Training Input Plan and historical data provided by MCCES.

the classroom or facility, the number of instructors required by the CDD, and the amount of available training aids.

Class scheduling has historically been calculated using the Training Input Plan (TIP) data. The TIP is a document developed by higher headquarters that estimates the total number of Marines expected to pass through the system per trimester per fiscal year. The TIP becomes the source document used for planning and scheduling purposes at MCCES.

In the current process of scheduling classes, the projected annual arrivals from the TIP are divided by the maximum class size to derive the total number of classes required per fiscal year. Once the total number of required classes has been determined, class start-dates are spread fairly evenly throughout the year. It is important to note that arrival rates are not constant nor are arrivals of Marines of a specific MOS evenly distributed throughout the year. This variability in Marine arrivals results in large Marines Awaiting Training (MAT) queues. Lastly, although a pre-determined number of billets exist for instructors, the actual staffing level is determined by higher authority and is often below the number of billets.

To further complicate MCCES operations, the number of available instructors per MOS fluctuates at any given time for additional reasons such as leave and Temporary Additional Duty (TAD). For example, Company B supports the Marine Corps through Individual Augmentees, Warfighter Training Requests, Mobile Training Teams, and support of intra-battalion billets. Further, Company B locally teaches five Non-Commissioned Officer (NCO) courses in the 065x MOSs per annum. Each NCO course requires three instructors and personnel required to support the NCO course are sourced from within Company B without backfilling the instructor billet. These duties, in extreme cases, have resulted in the cancellation of classes in the past due to insufficient instructors.

The instructors, lecture halls, and laboratories were all modeled as resources. In order to prevent training from taking place on non-working days, the instructors were scheduled to not work on all weekends and holidays. It is important to note that policy dictates that each class requires two instructors. Table 2 displays the course training specifics, including the actual number of instructors available to teach.

MOS	Min Class Size	Max Class Size	Available Lecture Halls	Labs Available	Instructors Assigned	Minimum Instructors per class	Training Days per Class
0612	14	20	3	N/A	7	2	17
0614	5	10	2	N/A	4	2	40
0621	20	45	8	N/A	25	2	30
0622	20	27	2	N/A	3	2	30
0623	10	13	1	N/A	3	2	31
0651	15	30	6	1	11	2	30
0656	15	20	4	2	12	2	41

Table 2. MOS Course Training Specifics.[7]

C. PHYSICAL AND POLICY CONSTRAINTS

MCCES is bound by both physical and policy constraints. They have a limited amount of classrooms and laboratories and the quantity of instructors is ultimately determined by higher headquarters with MCCES input. Also, in time of war or crisis, the course length can be shortened to meet “mobilization” criteria where courses are shortened by extending the hours of instruction each day and the number of training days per week. MCCES also levies a policy constraint that limits the size of the classes to a minimum and maximum number of studenets. However, there are physical constraints (i.e., the number of students that the room can accommodate) that are also a valid variable. Lastly, although MCCES is authorized to have a specific number of instructors by MOS, that number can vary as higher headquarters’ requirements can cause a particular billet to be left open forcing MCCES to “do more with less.” Table 3 displays the physical and policy constraints.

[7] Max Class Size based upon physical constraints was provided by the staff at Company B.

MOS	Normal Length (days) (Policy Constraint)	Mobilization Length (days) (Policy Constraint)	Min Class Size (Policy Constraint)	Max Class Size (Policy Constraint)	Max Class Size (Physical Constraint)	Lecture Halls Available (Physical Constraint)	Labs Available (Physical Constraint)	Instructors Authorized (Policy Constraint)	Historical Instructors Available (Policy Constraint)	Minimum Instructors per class (Policy Constraint)
0612	17	14	14	20	25	3	N/A	7	7	2
0614	40	28	5	10	12	2	N/A	6	4	2
0621	30	24	20	45	50	8	N/A	27	25	2
0622	30	24	20	27	30	2	N/A	3	3	2
0623	31	21	10	13	15	1	N/A	3	3	2
0651	40	32	15	30	30	6	1	16	11	2
0656	41	32	15	20	27	4	2	18	12	2

Table 3. Current Physical and Policy Constraints.

The methodology to determine minimum and maximum class size was determined by the staffs of MCCES and Company B based upon physical constraints and policy constraints set by MCCES and higher headquarters. MCCES did not perform detailed statistical analysis to determine these numbers. There was some consideration of ergonomics and effective learning methods when considering these quantities. However, by applying simulation analysis, the researchers will illustrate where efficiencies can be gained.

D. ARRIVAL DISTRIBUTION

The Input Analyzer function in the Arena software suite analyses data and fits a probability distribution to that data, as well as calculates measures that show how well the distribution fits the data. Arena uses continuous theoretical distributions to output real values, typically used to represent time durations (Kelton et al., 2004).

Historical arrival data from FY06 was entered into Arena's Input Analyzer to determine the best distribution for generating the random number of Marines arriving on a given arrival day. In order to not skew the fitted distribution, weeks with zero arrivals were removed from the data file that was used to generate the "best fit" distribution. (To accurately account for weeks where there zero arrivals, the researchers determined the percentage of occurrences where there were zero arrivals from the current data, and then used a decision module to accurately model those periods within Arena.). The researchers allowed the "best fit" function to attempt to find the best fitting statistical distribution. This function determines the "best fit" by using the distribution with the lowest sum of squares error (SSE). However, the researchers discovered through trial-and-error that the "best fit" distribution provided by the Input Analyzer did not accurately reproduce the historical number of annual arrivals for each MOS. To counter this finding, the sample means and distribution means for each of several different distributions provided by Input Analyzer were compared for similarity. The researchers then selected from the list of distributions with means similar to the sample mean by using the lowest SSE to determine which distribution type provided by Input Analyzer was to be used in the model. The "best fit" distributions are depicted in Table 4 and detailed analysis can be viewed in Figures 11-17 in Appendix A. The variation in the number of arriving Marines is the only source of variability in the system, since the processing time for the Indoctrination Course and the processing time for each period of instruction are deterministic.

MOS	**Title**	**Arrival Distribution**
0612	Field Wireman	NORM (9.23, 5.33)
0614	Unit Level Circuit Switch Operator/Maintenance	0.5 + LOGN (2.83, 4.22)
0621	Field Radio Operator	0.5 + EXPO (25)
0622	Mobile Multichannel Equipment Operator	0.5 + EXPO (3.27)
0623	Transportable Multichannel Equipment Operator	0.5 + EXPO (2.33)
0651	Tactical Data Systems Operator	0.5 + EXPO (6.01)
0656	Tactical Data Network Operator	NORM (9.57, 6.9)

Table 4. MCCES MOS Arrival Distribution.[8]

The entire process is made up of activities that can be grouped into two categories; those activities that add value (command indoctrination, classroom training, and laboratory training) and those that do not add value (time spent in MAT, and time spent waiting to start command indoctrination).

[8] The Input Analyzer generated graphs and statistics summaries are Figures 11-17 and are included in Appendix A.

Statistical distribution of arrivals was determined using FY06 data only. Older historical data was available. However, because the growth rate of the 06XX MOS is not linear, only FY06 data was used. Using data prior to FY06 to determine arrivals would have skewed the data and would not have given an accurate representation of the current system. Further, with the certainty that U.S. Marine Corps end-strength will increase, it was imperative to create an accurate base-line of arrivals in order to make accurate recommendations with regard to gaining efficiencies and to make more efficient use of resources.

E. MODEL EXPLANATION

In order to better model the ongoing training system, the researchers modeled a 364-day warm-up period. In addition, at the beginning of the warm-up period, the researchers began the model system with classes in progress and Marines in the MAT queue. The starting condition for each modeled MOS (in both the scheduled and on-demand models) was created using actual data provided by Company B for the beginning of FY08. The researchers felt that using this more recent actual data would provide the most realistic starting condition for the model as historical data that illustrates daily conditions at MCCES in 2006 (i.e., number of Marines by MOS in training and in MAT) does not exist. Figure 5 displays the starting condition of each model.

MOS	Classes in Progress	Marines in Training	Marines in MAT
0612	1	24	0
0614	0	0	5
0621	2	60	91
0622	1	21	4
0623	0	0	1
0651	2	22	34
0656	4	56	38

Table 5. Starting Condition of Models.

Theoretical capacity does not change. Capacity is finite based upon factors such as instructors, classrooms, and training aids. This point is further illustrated when considering that the training system at MCCES can not train more Marines than are sent during a particular fiscal year. That is to say, regardless of theoretical throughput rate and capacity, if only 100 Marines of a particular MOS are sent to MCCES for training, MCCES can only train 100; thus its capacity is further constrained by the limited raw material (students) received for training. However, the researchers determined early in their research that available resources could be used more efficiently and cycle-time could be improved upon.

Statistics for the average time Marines spent in the MAT queue were collected for the 365 days following the warm-up period. In order to achieve a 95% confidence interval of approximately +/- one percent, the researchers ran the model for the number of replications determined as shown in Table 6. To determine the number of replications (n), the researchers used the equation:

$$n \cong n_0 \frac{h_0^2}{h^2}$$

where n_0 equals the number of initial replications, h equals the desired half width, and h_0 equals the half width that resulted from the initial number of replications (n_0). This configuration of the model formed the base scenario (Kelton et. al p. 262).

The researchers achieved half width accuracy of less than 1.5 days in 71% of the models. The MOSs where this was not achieved (MOS 0623 and MOS 0656 in the scheduled version only) was a result of their having a significantly large average number of days in MAT. Their accuracy was below the 1.5 day threshold in the on-demand models.

Scheduled Classes

MOS	Identifier	Average Days in MAT	Initial Half Width	Desired Half Width as a % of Avg Days in MAT	Desired Half Width in terms of days	Minimum Days in MAT	Maximum Days in MAT	Initial Runs	Minimum Number of Replications Required for 95% Confidence Interval
0612	MAT.Queue Avg Wait Time	25.028	1.28	0.025	0.6257	14.4469	61.5738	200	837
0614	MAT.Queue Avg Wait Time	46.606	3.35	0.025	1.1652	22.5932	187.89	200	1653
0621	MAT.Queue Avg Wait Time	16.9587	1.21	0.025	0.4240	6.2927	63.6574	200	1629
0622	MAT.Queue Avg Wait Time	56.8908	1.98	0.025	1.4223	30.3382	115.06	200	388
0623	MAT.Queue Avg Wait Time	111.47	4.8	0.025	2.7868	36.6486	230.7	200	593
0651	MAT.Queue Avg Wait Time	31.5547	1.33	0.025	0.7889	17.2809	81.9656	200	568
0656	MAT.Queue Avg Wait Time	86.7544	5.18	0.025	2.1689	21.817	193.56	200	1141

On Demand Classes

MOS	Identifier	Average Days in MAT	Initial Half Width	Desired Half Width as a % of Avg Days in MAT	Desired Half Width in terms of days	Minimum Days in MAT	Maximum Days in MAT	Initial Runs	Minimum Number of Replications Required for 95% Confidence Interval
0612	MAT.Queue Avg Wait Time	7.4621	0.1	0.025	0.1866	5.9604	9.904	200	57
0614	MAT.Queue Avg Wait Time	20.7099	2.05	0.025	0.5177	7.4024	109.98	200	3135
0621	MAT.Queue Avg Wait Time	4.4865	0.08	0.025	0.1122	3.2164	6.0732	200	102
0622	MAT.Queue Avg Wait Time	31.3707	1.08	0.025	0.7843	18.3	54.1912	200	379
0623	MAT.Queue Avg Wait Time	56.889	4.02	0.025	1.4222	12.9394	191.64	200	1598
0651	MAT.Queue Avg Wait Time	11.949	0.31	0.025	0.2987	7.3458	20.6623	200	215
0656	MAT.Queue Avg Wait Time	41.7056	4.1	0.025	1.0426	9.3528	150.57	200	3093

Table 6. Report for the Terminating Sequential-Sampling Run by MOS.

By building and analyzing a discrete-event simulation model for each of the 06XX training continuums, the researchers were able to obtain an average baseline of the time Marines spend awaiting training in each course.

F. ASSUMPTIONS

Instructor utilization rates, as statistical reference points generated by the model, assume that all instructors are available for every regular work day of the entire year. The researchers assumed that the historical number of instructors available for FY06 was based upon available instructors physically controlled by Company B, exclusive of intra-battalion staffing requirements. Further, Individual Augmentee (IA), Warfighter Training Requests (WTR), and Mobile Training Teams (MTT) requirements were not counted against the FY06 historically-available instructors due to inherent variability in duration and the unpredictable nature as to when external support to the Operating Forces would have been requested. Additionally, the data was not available. Because data was also not available to show the quantity of leave taken by an instructor, nor the periods that leave was taken, no attempt is made to simulate instructors in a leave status or performing other duties during the year. It is assumed that these periods are accounted for in the non-utilized time. During interviews with Company B personnel, it was noted that, when classes were scheduled in advance, the likelihood of canceling a class due to an insufficient number of instructors was extremely low and thus not considered for the model.

The researchers also assumed that all training aids, classroom facilities, and instructors identified by MCCES would be available for the scheduled model. The only exception to this is in the case of the 0656 MOS where the lab period of instruction has the physical capacity to instruct 20 Marines. Historically, one of the 10 training aids (two students per training aid) is down for maintenance at any given time, and as such, Company B plans for a maximum class capacity of 18 Marines even though the Course Descriptive Data states the maximum capacity of the course is 20.

Further, the model does not take into account students that fail out of the system after their class begins, nor does it take into consideration a student that is academically or medically set back and is subsequently recycled to MAT before restarting a later class. Both of these situations occur in a very small percentage and should not have a significant effect on the statistical output of the Arena model.

G. MODEL CREATION

The simulation model was developed using the Arena 10.0 simulation software by Rockwell Automation. Two models were created for each of MCCES' seven MOSs: one model to simulate the current scheduled operation and one to simulate an on-demand method.

1. Scheduled Classes

The scheduled-classes models have five main parts: creating Marines in training at time zero (Figure 4), Creating Marines Already in MAT at Time Zero (Figure 5), Simulating Arrival of Marines and Their Command Indoctrination Training (Figure 6), Creating Scheduled Classes (Figure 7), and Simulating the Training process (Figure 8).

By modeling the Marines in training in both classrooms and labs at time zero, the model can simulate the steady-state process of training Marines at MCCES. In addition to initiating the system with Marines already in training and waiting for training, a one-year warm-up period was used. Marines in training are modeled at the beginning of the simulation in batches, replicating formed classes that are progressing through training. Entities are assigned an attribute that is used to track total time in the system. Similarly, Figures 4 and 5 illustrate the logic for simulating the Marines in training and Marines in the MAT queue at time zero. Entities are then assigned an attribute that records their arrival time to the system.

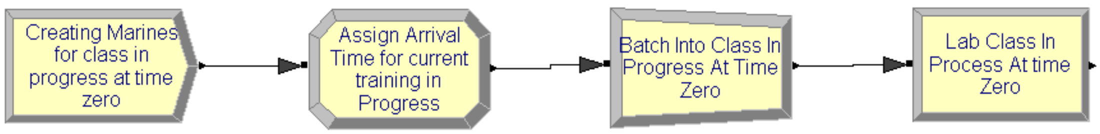

Figure 4. Example of Arena Logic for Creating Marines in Training at Time Zero.

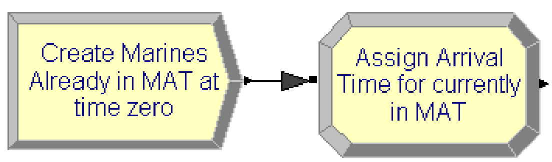

Figure 5. Example of Arena Logic for Setting up Marines in the MAT Queue at Time Zero.

Figure 6 shows the section of the model that "reads-in" the arrival days of Marines who could arrive on 49 Wednesdays of the calendar year. The 49 arrival days for each MOS were analyzed and the statistical arrival distribution was input into the model. There is then a delay until the next arrival day is reached. When the arrival day is reached, a decision module is used to determine if there are zero or a non-zero number of arrivals. (The percent of non-zero arrivals was determined by historical data, as discussed previously.) In the case of a non-zero number of arrivals, a random number of

Marines are then "created" according to the distribution stated earlier, and the arriving Marines are assigned their arrival time and their MOS attribute. Marines then proceed through the three-day Command Indoctrination training.

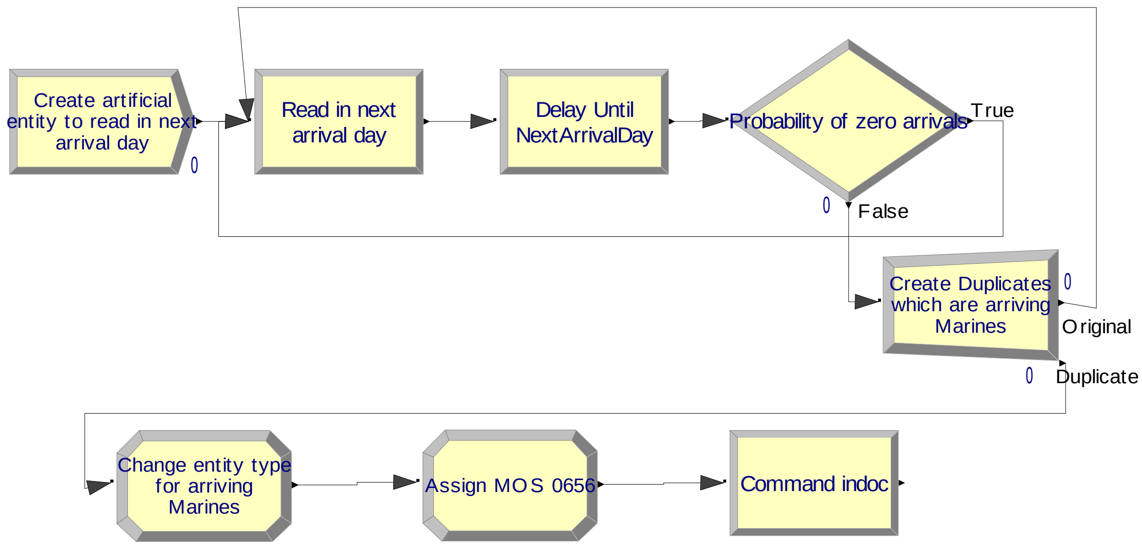

Figure 6. Example of Arena Logic for Simulating Arrival of Marines and Their Command Indoctrination Training.

The logic for creating the class start-dates is dependent on the amount of students awaiting training, as there are minimum and maximum class size limits. Figure 7 shows how a class start-time is read in from the file of actual scheduled class starts; if the minimum number of students is met in the MAT queue, a signal to start a class is sent. In order for Arena to accurately simulate a simultaneous class start, the researchers needed to increase time slightly to make sure releasing students from holding in the MAT queue, setting class size, and batching happened in the correct sequence.

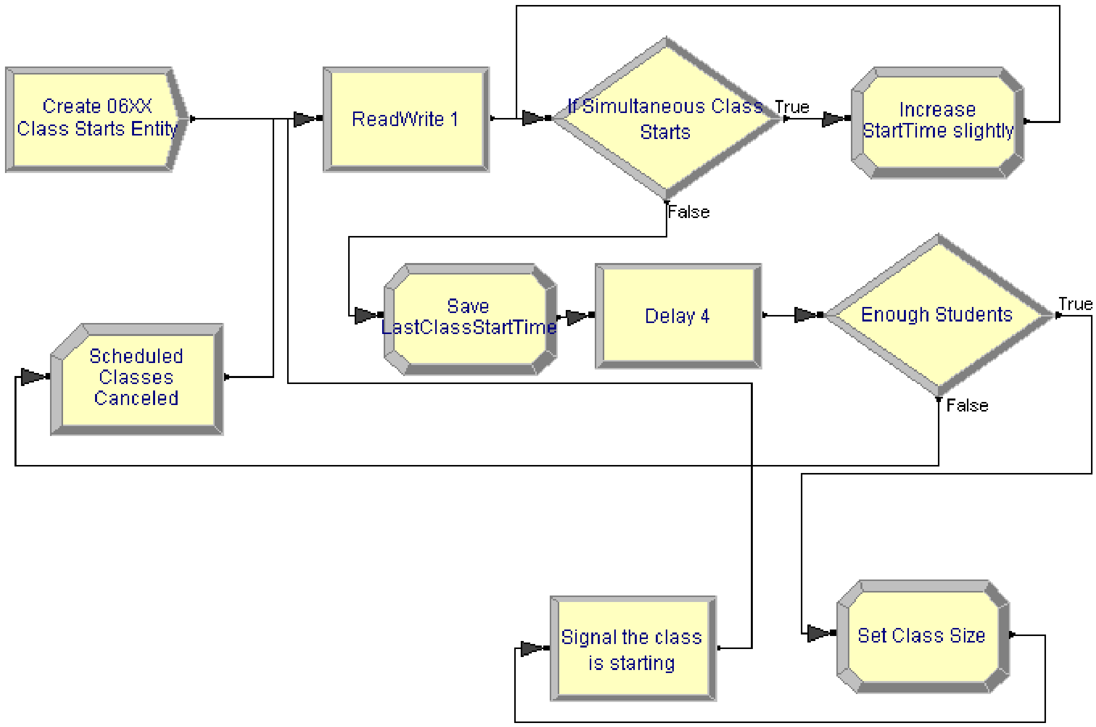

Figure 7. Example of Arena Logic for Creating Scheduled Classes.

Figure 8 shows how a Hold module named MAT is used to simulate students waiting for a signal that a scheduled class is starting. Once the signal is sent, all students are released from the MAT queue with a limit up to the maximum students allowed per class in a First-in-First-out priority, as shown in Figure 8. Setting a class size variable ensures that the number of Marines batched into a class exactly equals the number of Marines that were released from the MAT queue to begin training. Any remaining students in the MAT queue must wait there until the same requirements are met to teach another class.

Once the Marines are batched into a class, the class then proceeds through the lecture and lab class sessions where applicable. Classes use instructors for both the lecture and the lab portions of the training, as shown in Figure 8. Once the class completes the lab, the Marines are then separated and counted for graduation.

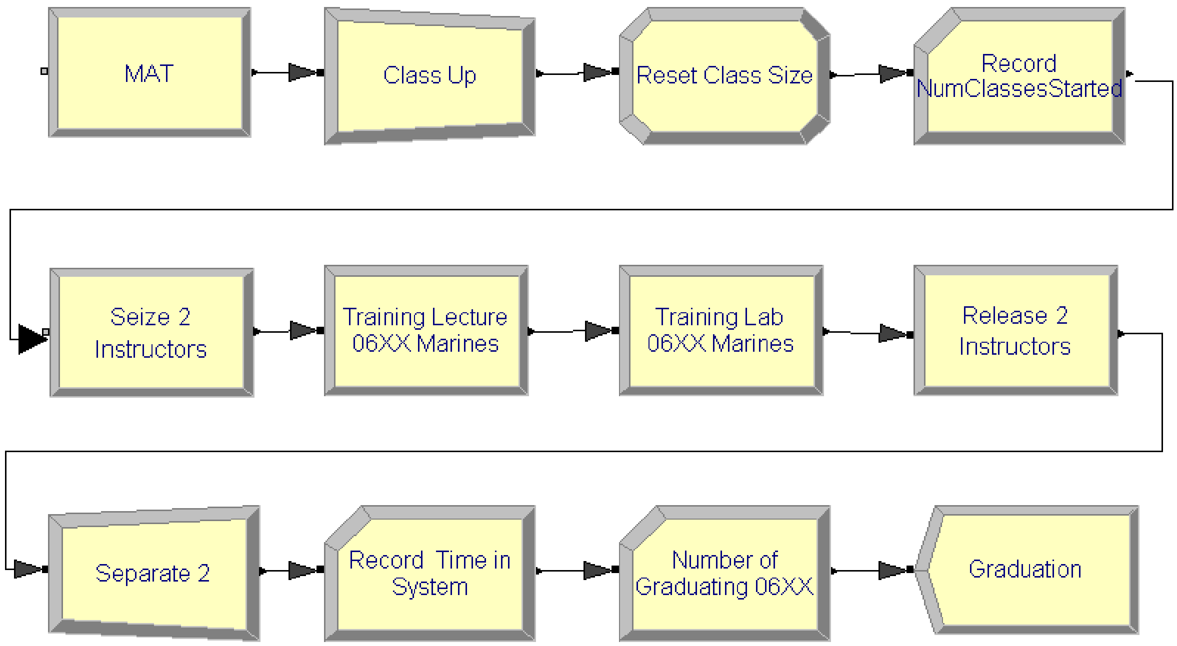

Figure 8. Example of Arena Logic for Simulating the Training Process.

2. On-Demand Classes

The on-demand model has six main parts: four of these parts are the same as the model using a schedule for class starts. Arriving students and previously existing students in the system are created in the same manner as in the scheduled-class model. In addition, the process of reaching the MAT queue and the actual training process are the same in both the on-demand and in the scheduled models.

The main difference between the models is that on-demand model classes are started immediately if four conditions are met. These conditions are: are the minimum number of instructors available, are there enough students in MAT to meet the minimum number of students required, has the maximum number of students been exceeded, and is the classroom available. There is a slight difference between the 06XX MOSs and the 0656 MOS in that the 0656 MOS has an additional laboratory requirement that must be met. In order to correctly start classes and ensure the queue remains in MAT instead of between the two processes simulating the lecture and laboratory portion, a variable was created: "numlabswillbeavailable." This variable is changed on a counter that is decreased when a class enters the lab process and is increased when the existing class in the lab process has completed enough time in the lab. By incrementing and decrementing, the lab will be available immediately for a class to use when the class finishes the lecture process. This ensures that no class will have to wait for a lab after finishing the lecture. This availability is required to ensure the comparison of the models is exclusively between scheduled and on-demand class starts. The actual process at MCCES schedules the class starts to transition between the lecture and lab processes without waiting. In the scheduled model, logic had to be created to evaluate the minimum and maximum class sizes for that MOS in order to determine if a class would start corresponding with the start schedule. But in the on-demand model, the model has to evaluate resource availability, as well as the minimum and maximum class size constraints.

While students wait in the MAT queue for a class-start signal, the part of the model shown in Figure 9 scans for a minimum sufficient number of students to start a class, for two available instructors, and for an available lecture classroom. The logic depicted in Figure 9 at time zero creates a signal to "hold" the class and prevent it from starting without enough instructors and without a number of students above the minimum required and below the maximum allowed. In addition, an available lab is ensured by checking that the value of "numlabswillbeavailable" is greater than zero. The condition statement in the signal module is: ((NQ(MAT.Queue) >= minclass) && (NR(Instructors) <= num0656instructors-2) && (NR(Lecture Halls) < 2) && (numlabswillbeavailable > 0)).

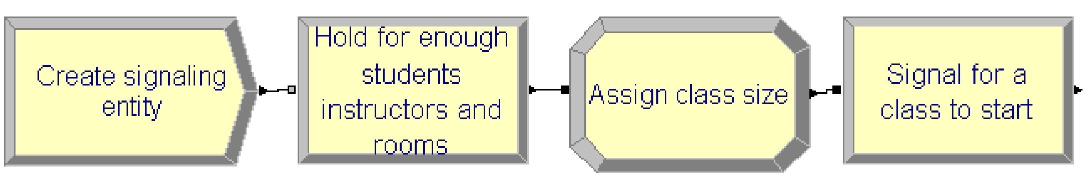

Figure 9. Process to signal when a class can start.

As Figure 10 depicts, in order to evaluate the number of lab classrooms available, the logic initializes the variable of “numlabsavailable” equal to two. Then, it begins the system warm-up. The variable is decreased by one when a class enters the lecture process to guarantee a lab is reserved for that class entering the lecture process. The variable is increased from zero (if both labs were in use) after a time delay that begins after the class begins the lecture process, but before it enters the lab process. The length of the delay before increasing “numlabsavailable” is equal to the duration of the lab process minus the duration of the lecture process. Also listed as variables in the model are “Labdays” and “Lecturedays,” which permit use of the Process Analyzer (PAN) feature of Arena.

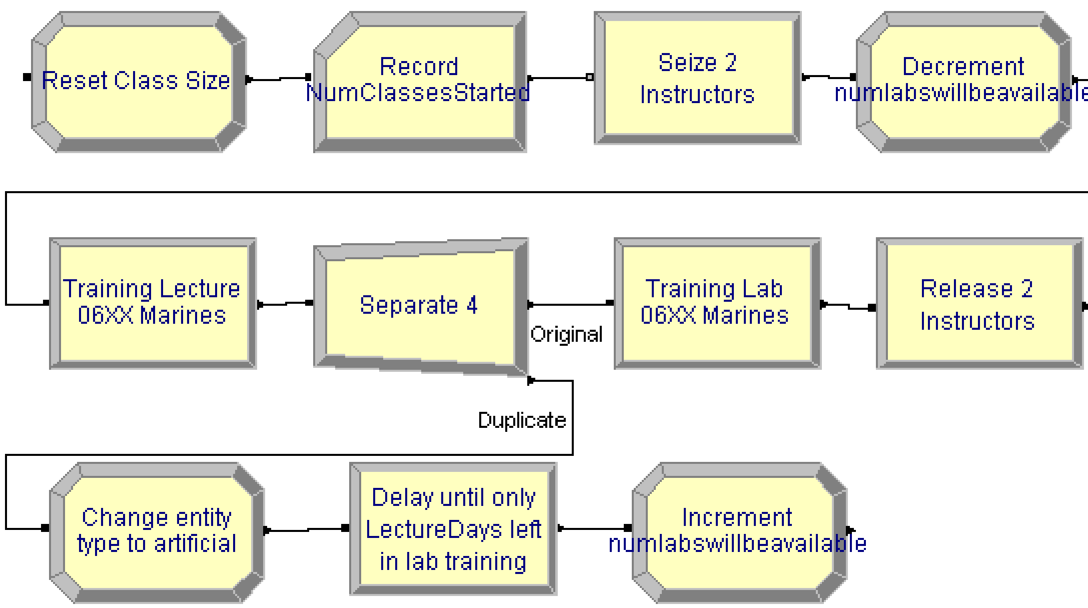

Figure 10. Example of Arena Logic for Decrementing and Incrementing the Number of Lab Classrooms Available to Allow the Evaluation of Whether a Lab Will be Available Before Class Starts are Allowed.

The fundamental difference between the on-demand and scheduled models is when each class within each MOS starts. The training process once the first day of each MOS course starts is identical between the two models. The researchers did have to use additional capabilities within Arena to ensure that each model performed accurately; however, these additional modules did not change the actual classroom process.

V. MODEL VALIDITY, EXPERIMENTAL DESIGN, AND RESULTS

A. MODEL VALIDATION

For each of the seven, entry-level MOSs simulated, the existing system model produced and graduated Marines very close to the actual numbers as per FY06 historical data provided by MCCES. The number of classes begun and graduated for the existing system model also closely matched the FY06 historical data. Differences in arrivals and graduates can be attributed to inherent variability of Marines "created" by the arrival distributions in Arena. Further, differences in classes begun or canceled in the scheduled model versus the actual system can be attributed to the fact that on occasion MCCES has started scheduled classes with less than their published minimum number of students and in other cases has started scheduled classes with more than their published maximum number of students.

B. EXPERIMENTAL DESIGN

In order to determine which potential system improvements to investigate, the researchers chose to look at changes that could be implemented by the local commander, although possibly requiring permission from higher authority. These potential improvements would not incur any capital investment. After discussions with MCCES, it was determined that the following changes would be considered: switching from scheduled classes to on-demand classes, altering the minimum and/or maximum number of students required to begin a class, a compressed class duration, and increasing the actual number of instructors to the number of instructors authorized. These investigated changes include both physical and policy constraints in an effort to find ways to significantly improve the current system. The measures used to determine the effects of these changes on the system include average MAT waiting times, average number of Marines in MAT, and instructor utilization.

The change to an on-demand class system was investigated because based on bottleneck analysis of available data, the MAT queue became very large as Marines arrived regardless of when their MOS class was scheduled to begin. These Marines required oversight of staff personnel further burdening the system. The manpower used to manage the MAT platoon could be better utilized elsewhere in the system and the cost of this manpower represents inventory holding costs. In this situation, capacity (scheduled classes) is made to closely match demand (number of arriving Marines) in a system with high variability (arrivals) which results in very large queues.

The option of decreasing the length of each class consists of increasing the training day to 10 hours per day from eight, and increasing the work week to six days per week from five. This option decreased the course lengths from anywhere between three days to 12 days and could be implemented in times of crisis when throughput is critical. Decreasing the training length was also explored because the researchers wanted to investigate the effects on MCCES should mobilization be ordered by higher authority. The researchers believed that, in conjunction with an on-demand class schedule, mobilization could significantly increase the throughput of MCCES during time of national emergency or when ordered by higher authority. In addition, it was important to assess the impact other changes would have during periods of mobilization when the change to a shorter class duration is necessary.

When analyzing available data, the researchers noticed that there were periods when Marines waited for training longer than their actual MOS training required. This was especially evident in MOSs where the annual throughput is low. These findings led the researchers to explore the policy restrictions for minimum and maximum class sizes as well as the physical constraints of the individual classrooms and then vary these parameters in the model to determine their effects.

The researchers analyzed MCCES manning documents to find the authorized manning level of instructors for each MOS. Although the number of instructors was not a significantly limiting factor in the current system (probably because additional classes would not be scheduled if instructors were not available to teach them, the researchers felt it was important to examine the effect of increasing instructor manning up to their maximum level when investigating other potential changes to the system. This was an important aspect of analyzing on-demand scheduling, given the additional out-of-classroom responsibilities the instructors have and the additional classes that the instructors will be assigned to instruct.

The researchers investigated between 16 and 32 scenarios for each MOS by using the Process Analyzer Function (PAN) in Arena. A complete listing of the various scenarios built using PAN, along with the results for each scenario, are shown in Tables 12-18 which are located in Appendix B, with the chosen parameter levels discussed below by MOS in Section C. In MOS 0612, MOS 0622, and MOS 0623, the actual number of instructors assigned equals the amount of instructors authorized, thus, in these scenarios, there are only four variables to consider. The amount of scenarios to use was determined by the possible combinations of the variables that were deemed relevant as a result of the researchers' hypothesis and interviews with MCCES personnel. The number of required scenarios is mathematically explained by using the equations: $2^5 = 32$ and $2^4 = 16$. After performing preliminary runs, some MOSs required additional scenarios that the researchers considered relevant. These additional scenarios and their results are discussed in section C of this chapter.

C. DESIGN PARAMETERS AND RESULTS BY MOS

1. MOS 0612

a. Design Parameters

For MOS 0612, the researchers explored 16 different scenarios that could be implemented by MCCES─ scheduled versus on-demand classes, course length, minimum class size, and maximum class size. The number of available instructors was not varied because the number of instructors assigned equals the number of instructors authorized.

The current system directs a minimum class size of 14 and a maximum class size of 20. However, after analyzing the process at MCCES, the researchers felt that it was necessary to explore a maximum class size of 25. This change could be implemented as the physical capacity of the classroom and the training aids could permit an increase of five Marines. Of note, MCCES historical data indicates that one 0612 class was cancelled due to insufficient minimum numbers during FY06. However, on two occasions during FY06, MCCES convened classes with less than the published minimum, thus lending validity to considering the change to an on-demand system.

b. Results

The best single change option is an on-demand scheduling routine. This change results in a reduction from an average 24.23 days in queue to an average of 7.91 days, representing a 67% savings in days spent waiting. Further, the average number of Marines waiting decreases from 24.16 to 7.91, also a 67% reduction. Interestingly, instructor utilization increases only slightly from 46% to 50%.

Implementing the least beneficial improvements (increasing minimum required to 20 and maximum class capacity to 25) yields an 11% reduction in average waiting time. Further the average number of Marines waiting decreases by 11%. The easiest single change that MCCES could implement immediately is to increase the maximum number of students per class from 20 to 25, holding all other variable constant. This one change yields an average of 27% reduction in waiting time.

The most improved system configuration, leaving the course at the 17-day schedule, would be to switch to on-demand scheduling and increase maximum class size to 25 Marines. In every MOS, enacting the shortened schedule (mobilization) would result in only a minimal improvement to the system, but it may result in a negative effect on the quality of training and was thus not considered a viable option. These two minor changes to the current system would decrease in the average days spent waiting in MAT from 24.24 days to 7.30 days and would decrease the average number of Marines waiting in queue from 24.16 to 7.29, representing a reduction of 70% for each. Average instructor utilization goes up slightly from 46% to 48%.

2. MOS 0614

a. Design Parameters

For MOS 0614, the researchers explored 32 scenarios that could be implemented by MCCES─ scheduled versus on-demand classes, course length, minimum class size, maximum class size, and number of instructors.

Currently, a policy constraint exists as to the maximum class size of 10 Marines. After examining the process at MCCES, the researchers determined that an additional two Marines could be added to the class without negatively affecting training. This change can be implemented as the physical space and training aids will accommodate the addition. Further research indicated that MCCES actually convened two classes with more than the published maximum number of students.

b. Results

Changing from the current system to an on-demand system provides a reduction of average wait times and average number of Marines waiting in MAT without convening any classes above the maximum number of students. Specifically, the average wait time falls from 48.96 days in the queue to an average of 21.86 days for an average reduction of 55%. The number of Marines in MAT falls from an average of 12.12 to 5.68, for an average decrease of 53%.

The least beneficial change to the current system, increasing maximum class size to 12, results in an 18% reduction in average MAT waiting time and the average number of Marines decreases by 20%.

The best system configuration option available, while holding the course length steady at 40 days, would be to adopt an on-demand scheduling, increase the number of available instructors to six[9], and to increase maximum class size to 12. Implementing these changes would yield an average reduction of 64% in both wait times and number of Marines waiting. The average number days waiting falls from 48.95 to

[9] MCCES is authorized six instructors for MOS 0614.

17.50 and the average number waiting falls from 12.12 to 4.39. Instructor utilization decreases from 91% to 69%, resulting in additional free time for the development of instructional material, participation in additional training, or other command employment opportunities.

3. MOS 0621

a. Design Parameters

For MOS 0621 the researchers explored 32 scenarios by investigating all five changes that could be implemented by MCCES─ scheduled versus on-demand classes, course length, minimum class size, maximum class size, and number of instructors. Maximum class size per the Course Descriptive Data (CDD) is 45. From their analysis of the current system, the researchers feel that the maximum class size could be expanded to 50 without any negative effects to the training system. After examination of processes at MCCES, and a review of historical data, the researchers noted on six occasions during FY06 MCCES convened classes in excess of the published maximum. With this in mind, the researchers determined that the expansion is a viable option.

b. Results

Modifying from the current system to on-demand classes provides a reduction in MAT waiting times. The average waiting time decreases from 16.89 days to 4.51 days, an average reduction of 73%. The average number of Marines waiting in MAT also falls significantly by 76% from 55.47 to 13.24 days.

Using the current scheduled class system, course length, and minimum class size, while increasing maximum class size to 50 and increasing number of available instructors to 27, provides the least beneficial change to the system that results in an 18% reduction in average MAT wait times and a 15% reduction in average number of Marines waiting in MAT. Increasing the maximum number of student per class to 50 represents simplest change in isolation MCCES could put into action. Allowing for five additional students per class reduces average waiting time by 18%.

Finally, the best system improvement option explored resulted in a 74% average reduction in waiting time and a 77% average reduction in the number of Marines waiting. The instructor utilization is minimally increased from 30% to 32%. This best system configuration consists of on-demand classes and increasing the maximum number of students per class to 50. The researchers discounted the recommendation of increasing class size to 50 because of ergonomic considerations and the possibility of a degradation in the quality of training with a larger class size.

4. MOS 0622

a. Design Parameters

For MOS 0622 the researchers examined 24 different scenarios that could be initiated by MCCES in an attempt to reduce both the MAT wait time and the number of Marines waiting in MAT. The variables considered were: scheduled versus on-demand classes, course length, minimum class size, and maximum class size, yielding the first 16 scenarios. Varying the number of available instructors was not considered because the number of assigned instructors equals the number of instructors authorized. The published maximum class size is 27; however, after investigating the current system, the researchers determined that a maximum class size of 30 is possible. Further, by analyzing the arrival distribution of Marines, the researchers noted that in several cases there were periods when Marines waited longer than 30 days for a class. This finding led the researchers to examine the effect of lowering the minimum class size. This additional change resulted in the development of eight additional scenarios.

b. Results

Adjusting to an on-demand system, holding all other variables constant, reduces the average MAT waiting time from 56.22 days to of 31.26 days, resulting in a 44% average reduction. Similarly, an average of 44% reduction in the average number of Marines waiting occurs.

The least beneficial change to the current system would be to increase the maximum number of students from 27 to 30 thereby reducing both the average wait time and the average number of Marines waiting by 7%. The simplest change to the current system MCCES could implement would be to decrease minimum class size to 10 while holding all other variables constant. By adopting this one change, the average wait time falls by 29% and the number of Marines in MAT falls by an average of 28%.

The most improved system configuration the researchers examined generated significant reductions in both average waiting time and average number of Marines waiting. The resultant drop in each was 73% and 74%, respectively. Instructor utilization increases from 19% to 39%. This improved system consisted of an on-demand system, lower minimum class size, and increased maximum class size. Under this scenario, it is worth noting that the difference between a maximum class size of 27 and a maximum class size of 30 is miniscule (14.826 average days versus 14.893 average days, respectively) and does not affect the outcome.

5. MOS 0623

a. Design Parameters

Twenty-four scenarios were considered while analyzing the 0623 MOS. Changing the minimum and maximum class size in the 0623 MOS has a tremendous benefit. While analyzing the arrivals of Marines, the researchers noted that there were periods when Marines waited longer than 30 days to begin training. This resulted in the researchers analyzing the affects of reducing the class size to five which accounts for the additional eight scenarios for this MOS. Additionally, the researchers chose to examine the possibility of increasing the class size to a maximum of 15, the actual physical constraint of the facility. Varying the number of available instructors was not considered because the number of instructors assigned equals the number of instructors authorized.

b. Results

By expanding the maximum class size to 15 and reducing the minimum required class size to five will result in a decrease in the average days spent in the MAT queue of 33.6% (decreasing from an average of 112.513 to 74.739 days) and a decrease in the average number of Marines in the MAT queue of 35.9% (decreasing from an average of 9.308 to 5.969 Marines). In every scenario where the minimum class size was reduced to five, instructor utilization did not increase above 20% from the current 13.2%.

The best single change is increasing the maximum class size to 15 resulting in a reduction in the average days in the MAT queue of 8.3% and a decrease in instructor utilization from 13.2% to 8.9%. There is no change in the average number of Marines in the MAT queue.

Changing to on-demand scheduling significantly reduces waste in the training system. The average number of Marines in the MAT queue is reduced to 4.393 from 9.308 (a 52.8% reduction) and the average days spent in the MAT queue is reduced to 53.965 from 112.513 (a 52.04% reduction). Instructor utilization decreases slightly from 13.2% to 12.8%.

By shifting to on-demand scheduling and expanding the minimum and maximum class sizes to five and fifteen respectively, the system will realize a decrease in the average days spent in the MAT queue of 85.01% (decreasing from an average of 112.513 to 27.437 days) and a decrease in the average number of Marines in the MAT queue of 74.8% (decreasing from an average of 9.308 to 2.343 days). Interestingly, instructor utilization only increases 6.5% increasing from 13.2% to 19.7%.

6. MOS 0651

a. Design Parameters

For MOS 0651 the researchers explored 24 different scenarios and determined that the configuration that would yield the largest improvement would be to change to on-demand scheduling and reduce the minimum class size to 10. The exploration of changing the minimum class size to 10 accounts for the additional eight scenarios and was examined after the researchers noticed that there periods when Marines waited longer than 30 days for a class to start.

b. *Results*

Remaining in the scheduled class parameter and changing the minimum class size from 15 to ten, there is a reduction in the average days spent in MAT of 17% and a decrease in the average number of Marines in the MAT queue by 17% thus yielding the greatest single improvement to the system.

Moving from the current policy in use, and by shifting to an on-demand method of scheduling, holding all other variables constant, results in a decrease in the average days spent in MAT of 48% and a decrease in the average number of Marines in the MAT queue by 49%.

Incorporating both the on-demand method of scheduling and decreasing the minimum class size to 10, yields a reduction in the average days spent in the MAT queue of 66% (from 21.112 days to 7.259 days) as well as a decrease in the average number of Marines in the MAT queue of 66% (from 13.43 to 4.559). Instructor utilization increases slightly from 24.5% to 28.6%.

7. MOS 0656

a. *Design Parameters*

For MOS 0656 the researchers analyzed 32 scenarios. Although the current system dictates a minimum class size of 15, the researchers felt it was necessary to examine the effects of changing to a minimum of 18 students to be sure there was no benefit to be gained from that change. It is also possible to change the maximum class size by allowing three students to sit at each training aid in the laboratories rather than two. This would increase the maximum class size to 27 students and this option was also explored.

b. *Results*

The single change that produces the best results in terms of MAT queue reduction is adjusting to an on-demand scheduling routine. This change results in a reduction from an average 86.706 days in queue to and average of 42.779 days, representing a 51% savings in days spent waiting. Further, the average number of Marines waiting decreases from 95.39 to 47.78 days. Interestingly, instructor utilization increases only slightly from 65% to 67%.

The next best option for MAT queue reduction within the purview of the local commander at MCCES is to change the maximum number of students in class from 18 to 27, thereby reducing the average queue time from 86.706 days to 21.805 days, a 75% reduction in waiting. The average number waiting decreases from 95.385 to 23.661. Average instructor utilization also decreases from 64.8% to 50.2%.

The most improved system configuration, leaving the course at the 41-day schedule, would be to switch to on-demand class scheduling, and increase the maximum class size to 27. This would reduce the average days spent in MAT to 7.52 days, with an average number of Marines in the queue of 8.185. Instructor utilization decreases from 64.8% to 57%. This system would result in a decrease in waiting time by 91.3%, and a reduction of the average number of Marines in MAT by 91.4%.

D. SIMULATION RESULTS SUMMARY

Based upon interviews with MCCES staff and the former Commanding General of Training Command, Brigadier General M. Speise, the researchers determined that changing to an on-demand system would have the greatest affect on the training at MCCES and it is a change that the local commander can employ. This single change would result in a significant decrease in MAT waiting times and decrease the number of Marines in MAT. By adopting this one change and holding all other variables constant, significant efficiencies are gained over the current system. Table 7 provides a comparative summary of statistics between the current scheduled class system employed by MCCES and the researchers' proposed on-demand system. Holding all other variables constant and changing to the on-demand scheduling method, the system realizes reductions in the average days spent in MAT ranging from 44.39% to 67.36% as well as a reductions in the average number of Marines in the MAT queue ranging from 44.87% to 76.13%.

		Current System			On-Demand Scheduling		
MOS	Current System	Average days in MAT	Average number of Marines in MAT	Instructor Utilization	Average days in MAT	Average number of Marines in MAT	Instructor Utilization
0612	Scheduled - 17 days - 7 instructors - Min class 14 - Max class 20	24.239	24.162	0.457	7.912	7.906	0.502
0614	Scheduled - 40 days - 4 instructors - Min class 5 - Max class 10	48.953	12.117	0.910	21.861	5.679	1.066
0621	Scheduled - 30 days - 25 instructors - Min class 20 - Max class 45	16.881	55.472	0.303	4.51	13.243	0.338
0622	Scheduled - 30 days - 3 instructors - Min class 20 - Max class 27	56.218	16.441	0.118	31.264	9.064	0.211
0623	Scheduled - 31 days - 3 instructors - Min class 10 - Max class 13	112.513	9.308	0.132	53.965	4.393	0.128
0651	Scheduled - 40 days - 16 instructors - Min class 15 - Max class 30	21.112	13.43	0.245	11.046	6.919	0.286
0656	Scheduled - 41 days - 12 instructors - Min class 15 - Max class 18	86.706	95.385	0.648	42.779	47.788	0.665

Table 7. MOS Summary Results Based Upon the Current System of Scheduled Classes Versus an On-demand System Holding All Other Variables Constant.

One inefficiency of using a scheduled class schedule can be explained using Table 8. Of significance is the actual number of class cancellations and the number of classes started in FY06 with below the required minimum class size or above the stated maximum class size. For example if MOS 0621 is examined, there were 48 classes scheduled, eight were cancelled, and 8 started with either above the stated maximum number of students or with less than the stated minimum required class size. By using on-demand scheduling, the system was able to achieve near identical throughput as the scheduled model with only 26 class starts, all class sizes being within the minimum and maximum, and, more importantly, with a significant reduction in the average number of Marines in the MAT queue and a significant decrease in the average number of days spent in the MAT queue. Also, an on-demand schedule will suffer no class cancellations. Herein lies the removal of *muda*; reducing the amount of paperwork and the employment of additional resources involved in the administration of the MCCES system.[10]

[10] When classes are added or cancelled associated paperwork is generated at MCCES and forwarded to Training Command.

	FY06 Actual				As Modeled		
MOS	Class Starts	Cancellations	Class Starts Below Class Minimum	Class Starts Above Class Maximum	Scheduled Average Class Starts	Scheduled Average Class Cancellations	On-demand Average Class Starts
0612	23	1	2	0	17	7	18
0614	12	0	0	2	8	4	9
0621	40	8	1	7	25	13	26
0622	7	0	4	1	5	2	6
0623	5	0	0	2	3	2	3
0651	15	1	7	0	11	5	12
0656	20	7	0	2	18	9	20

Table 8. Class Starts and Cancellations Using Actual FY06 Data and Data as Modeled.

The researchers do not recommend that the mobilization course length be enacted in any of the MOSs. Lengthening the school day and extending the training week to include Saturdays may have a negative impact on the quality of training received by Marines at MCCES. However, it is important to illustrate the effects on average days in the MAT queue, average number of Marines in the MAT queue, and instructor utilization under the mobilization caveat so that MCCES can use these results to assist them in planning for a mobilization period. Of the three measures that this research project focuses on (average days in the MAT queue, average number of Marines in the MAT queue, and instructor utilization) shifting to mobilization only resulted in a decrease in instructor utilization when all else is held constant. Further, when comparing different on-demand scheduling scenarios under mobilization, the difference in average days spent in MAT and average number of Marines in MAT queue is marginal for every MOS.

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VI. COST BENEFITS OF IMPLEMENTING IMPROVEMENTS

A. COST REDUCTION AS RESULT OF REDUCED MAT WAITING

Quantifying the time saved in MAT in terms of dollars can be examined using many different measures. Costs such as daily salaries of waiting Marines, costs in facilities maintenance, energy consumption, and support-requirements can be examined to illustrate potential costs savings. Use of Activity Based Costing (ABC) as a costing metric was considered and determined by the researchers to be beyond the scope of this paper because available data did not support such analysis. However, a study performed in 2004 by Navy Air Systems Command (NAVAIR), Orlando Training Systems Division using FY03 data used ABC to determine the average cost per day per entry-level C4 Marine.

For example, the NAVAIR study states that the average total cost per 0621 MOS Marine per training day for FY03 was $18,132.00. This number includes pro-share costs of all facilities at Twentynine Palms as well as all facility costs, and salary costs of both instructors and students. The total cost was determined by summing all costs to offer all classes for all MOSs and then that total cost was divided by the total number of Marines and then multiplied by the sum of days that they spend in class plus 12 waiting days.

Included in the costing data was an average wait time of 12 days. This average time was selected arbitrarily by the writers of the NAVAIR study and is a much shorter period than what the researchers of this paper found to be accurate. The researchers concluded from the given data that reducing the average days spent waiting in MAT would have a significant effect on the total cost per Marine per training day by reducing the total cost numerator.

B. VALUE TRANSFER AS A RESULT OF REDUCED MAT WAITING

A Marine’s salary can be viewed as an unavoidable cost. That is to say, a Marine will receive his salary no matter if he is a recruit, in training, or in the Operating Forces.

Using FY06 data provided by MCCES and composite salary rates from the Office of Management and Budget (OMB), the researchers determined the average daily salary cost per Marine for each entry-level MOS as shown in Table 9 (calculations are displayed in Appendix C). This average daily salary cost per Marine represents a daily cost to the tax payer and represents an opportunity cost[11] to the Operating Forces. For example, under the existing system if an MOS 0612 Marine waits an average of 24.239 days in MAT for a class to begin, the average cost to the tax payer in terms of salary is $3,979.56. Decreasing the time spent waiting to an average of 7.912 days per MOS 0621 Marine represents a value transfer of $2,680.57 from a non-value added process (waiting for class to begin) to a value added process (employing a fully trained 0621 Marine in the Operating Forces for the job the Marine was originally recruited to perform).

MOS	Cost Per Day	Average Days in MAT Reduction (On-demand)	Salary Savings (per Marine)	Average Days in MAT Reduction (All Recommendations)	Salary Savings (per Marine)	Total Salary Savings (Per MOS per year)(Using all recommendations)
0612	$164.18	16.327	$2,680.57	16.94	$2,781.21	$1,104,140.05
0614	$165.09	27.092	$4,472.62	31.45	$5,192.08	$519,208.05
0621	$161.92	12.371	$2,003.11	On-demand is the only recommendation		$2,349,650.75
0622	$162.44	24.954	$4,053.53	41.3	$6,708.77	$885,557.90
0623	$158.25	58.548	$9,265.22	85.076	$13,463.28	$457,751.42
0651	$170.94	10.066	$1,720.68	13.853	$2,368.03	$632,264.50
0656	$169.73	43.927	$7,455.73	79.186	$13,440.24	$5,658,340.95

Table 9. Salary Value Transfer by MOS.

C. OPPORTUNITY COST CONSIDERATIONS

Each day a Marine spends in MAT represents an opportunity cost to the Marine Corps. Days lost in MAT contribute to decreased operational readiness and wasted resources. MCCES provides a technically-competent, combat-capable Marine to the Operating Forces who then turns the combat-capable Marine into a combat-ready Marine. Time saved at MCCES is transferred to the Operational Commander whereby the gaining

[11] An opportunity cost can be thought of as the economic benefits that are forgone from using an asset in its best alternative use to the one under consideration.

unit can “configure” the C4 Marine with additional skill sets needed to accomplish the mission as determined by the Marine’s Commander. Further, the time is transferred to the Commander and not lost within the training continuum and represents a shift in labor; labor is saved at the school house and redistributed to the operating forces (D. Cuyno, personal communication, September 24, 2007).

If the aggregate process that begins when Marines begin Recruit Training and ends when they report to their first operational command is considered, that is to say, from day one at MCRD through reporting to the Marines first operational assignment, the beat-of-the-drum is MCRD because every step from there to the operating forces must be completed. It cannot be tempered because Marines who begin MCRD must receive MOS training. However, improvement in the formal schools performance is as valuable as improvement at MCRD when considering the total time it takes a Marine to complete the Training and Transient (T2) pipeline. The underlying conclusion is that the Operating Forces Commander would place value on the opportunity to train his newest Marines for an additional day or an additional ten days. That is to say, the Operational Commander would value the additional time given to him/her to add the extra components (i.e. skills sets) sooner rather than later. Quantifying this benefit to the Operational Commander is beyond the scope of this report but one can assume that it can be equated in terms of dollars and readiness. Lateral effects (i.e. spillover benefits) are highly probable, but are also beyond the scope of this report.

D. COST-REDUCTION AS A RESULT OF DECREASED USAGE IN BARRACKS AND BASE SUPPORT

The researchers determined that, of the data provided in the NAVAIR Study, the only two areas that would clearly show a reduction in costs are those that could be intuitively quantified by determining daily usage. That is to say, a reduction in the total time a Marine spends in the system would not result in a decrease in MOS course costs or classroom facility costs as these costs are realized when the Marine actually receives training (value-added time) and the focus of this report is to reduce the time a Marine spends in a non-value-added status (MAT platoon). This reduction in time equates to a reduction in the average number of Marines in the queue, which would result in fewer Marines on average for base facilities to support. The researchers reasoned that a decrease in usage (i.e., less time spent at MCCES per Marine and fewer Marines at any given time) of the barracks and base support facilities would result in a quantifiable reduction in the costs of those facilities. The daily costs of the barracks and base support expenses were determined summing the total costs attributable by MOS per the 2004 NAVAIR study, dividing by 365 to determine a daily barracks and support cost per MOS, and then dividing by the MOS' throughput to determine this daily cost per Marine. The sum is then multiplied by the throughput to determine the total savings per MOS per year. These savings are significant and could be re-allocated to other areas by the local commander. The range of savings, from $69,315.80 in MOS 0614 to $1,023,455.29 in MOS 0656, with a total of 1.9 million across all MOSs, represents a significant amount of tax payer dollars that can be more effectively used elsewhere within the DoD or the Marine Corps. Table 10 displays cost savings to the barracks and base support costs with calculations displayed in Appendix D.

MOS	Cost Per Day	Average Days in MAT Reduction (On-demand)	Savings per Marine	Average Days in MAT Reduction (All Recommendations)	Savings per Marine	Total Savings (Per MOS per year)(Using all recommendations)
0612	$24.80	16.327	$404.91	16.94	$420.11	$166,784.46
0614	$22.04	27.092	$597.11	31.45	$693.16	$69,315.80
0621	$24.01	12.371	$297.03	On-demand is the only recommendation		$348,413.50
0622	$29.13	24.954	$726.91	41.3	$1,203.07	$158,805.11
0623	Data Not Available					
0651	$26.77	10.066	$269.47	13.853	$370.84	$99,015.56
0656	$30.70	43.927	$1,348.56	79.186	$2,431.01	$1,023,455.29

Table 10. Cost Savings to Barracks and Base Support Costs by MOS.

E. OTHER IMPLICATIONS OF IMPROVEMENTS

The most far-reaching benefits of reducing the time spent in MAT are potential human capital benefits, potential improvements in the quality of training, and a potential increase in theoretical capacity. Some of these benefits may or may not be realized.

Potential human capital benefits could be more effective employment of staff members in temporary assignments outside of MCCES. Potential improvements in the quality of training could be more effective instruction, or better training material that may result from instructors having more time to develop curriculum. Potential increases in theoretical capacity could result from changes to MCCES policy.

Managing a large quantity of Marines that are waiting to begin training presents a challenge to the MCCES staff and uses critical time and resources that can be better utilized elsewhere. Further, time spent accounting for each Marine and attempting to gainfully employ them could be better used by the staff element of MCCES. This time could be used to improve the quality of instruction, and possibly examine processes that could benefit from Lean Six Sigma implementation. Further, the additional time could be used to perform other essential daily tasks, training in the Marine Corps Martial Arts Program (MCMAP), or any other tasks that add value to the individual involved in MAT management, MCCES, or the Marine Corps in general.

In addition, the 06XX occupational field makes up a large percentage of the Marine Corps. The increased ability of MCCES to react to requirements from National Command Authority, DoD, or HQMC (i.e., the ability to train more Marines in less time) makes their operation more valuable to stakeholders and more responsible to the tax payer. This particular aspect is currently pertinent because of the requirement to increase the end-strength of the Marine Corps. MCCES' ability to train Marines more efficiently and more quickly will make their transition to a larger force easier as well as less costly. In terms of the Theory of Constraints, they have increased their theoretical capacity not only without employing any additional resources, but at a cost savings to the Marine Corps and the tax payer.

Lastly, efficient employment of the most junior Marines can help instill the ideas of efficiency and the removal of waste into their mind set at the very beginning of their careers. This notion is critical to the expansion in the integration of Lean Six Sigma across the Department of the Navy as directed by the Secretary of the Navy in a memorandum titled, "Department of the Navy Objectives for FY 2008 and Beyond" (Department of the Navy, 2007). It also reinforces the notion of doing-more-with-less, a key component of the Marine Corps culture as well as being a prelude to the current condition of operating in a fiscally challenging environment.

It is important to note that the total costs savings discussed in this chapter will not result in an actual cash flow reduction. The primary document used in the researchers' attempt to quantify the results of improvements (NAVAIR, August, 2004) does not specify the how the total costs were derived. The total costs will consist of costs that are fixed and costs that are variable. The portion of the total costs that are fixed costs, or capacity costs, will continue even with a reduction in the number of students; they are unavoidable in the short term. Conversely, a portion of the total costs are variable costs, costs that will increase and decrease in direct proportion to the number of students in training. The variable cost portion of the total cost will result in an actual cost reduction if the number of students in training is reduced. The researchers' ability to identify the variable cost portion of the total costs, which will result in an actual cost savings, is beyond the scope of this report.

VII. SUMMARY, CONCLUSIONS, RECOMMENDATIONS, AND AREAS FOR FURTHER ACTION AND RESEARCH

A. SUMMARY AND CONCLUSIONS

Arena software allowed the researchers to simulate the current operations at MCCES and then test and evaluate changes in the system. The software enabled them to simulate a total of 160 different scenarios with over 200,000 random arrivals within the seven MOSs that fall under MCCES, Company B. The model logic, while complex, closely simulated current conditions in Company B.

It is possible that human nature favors implementing broad new ideas rather than putting forth the intense effort required to continually improve upon a process. However, individuals involved in a process can likely be the best source for ideas on improving that process. These home-grown, often easy-to-implement, ideas can be both beneficially and widely accepted by an organization simply because of their origin. The immediate benefit to the quality of an individual's work life or the elimination of wasted time can help that individual's outlook on his/her job and, in turn, how that person's employer values him or her (Manos, 2007). If the researchers' recommendations are to be accepted by employees, employees must be presented with other benefits that consider their individual needs such as their style of work methods, mind-set, and other intangible benefits.

Following basic TOC process analysis and queuing analysis, the researchers were able to reduce flow time by manipulating the constraint (scheduling process) to: reduce down times, improve job scheduling and more effectively use the constrained resource (class starts). These improvements are depicted in Table 11.

The recommendations for the system are to:

1. Shift to on-demand class scheduling for every MOS.
2. For MOS 0614 increase the instructors to six and increase the maximum class size to 12.

3. For MOS 0622 decrease the minimum class size to ten.

4. For MOS 0623 decrease the minimum class size to five and increase the maximum class size to 15.

5. For MOS 0651 decrease the minimum class size to 10.

6. For MOS 0656 increase the maximum class size to 27.

The researchers determined that changing from the present MCCES process of scheduling classes to an on-demand scheduling method, changes to the minimum and maximum class sizes, and the number of instructors, would result in a significant reduction in the average days spent in MAT, a reduction in the average number of Marines in MAT, and could be quantified in terms of salary savings and cost-reduction as a result of decreased usage in the barracks and base support facilities. By utilizing all recommendations, the researchers recognized a potential value savings in terms of salary of $11.6 million and a potential cost savings to the barracks and base support facilities of $1.9 million.

MOS	Current System	Average days in MAT	Average number of Marines in MAT	Instructor Utilization	Recommended System (changes only)	Average days in MAT	Average number of Marines in MAT	Instructor Utilization
0612	Scheduled - 17 days - 7 instructors - Min class 14 - Max class 20	24.239	24.162	0.457	On-demand	7.299	7.289	0.475
0614	Scheduled - 40 days - 4 instructors - Min class 5 - Max class 10	48.953	12.117	0.910	On-demand 6 instructors Max class 12	17.503	4.392	0.688
0621	Scheduled - 30 days - 25 instructors - Min class 20 - Max class 45	16.881	55.472	0.303	On-demand	4.51	13.243	0.338
0622	Scheduled - 30 days - 3 instructors - Min class 20 - Max class 27	56.218	16.441	0.118	On-demand Min class 10	14.918	4.343	0.368
0623	Scheduled - 31 days - 3 instructors - Min class 10 - Max class 13	112.513	9.308	0.132	On-demand Min class 5 Max class 15	27.437	2.343	0.197
0651	Scheduled - 40 days - 16 instructors - Min class 15 - Max class 30	21.112	13.43	0.245	On-demand Min class 10	7.259	4.559	0.367
0656	Scheduled - 41 days - 12 instructors - Min class 15 - Max class 18	86.808	95.483	0.618	On-demand Max class 27	7.52	8.15	0.570

Table 11. Potential Improvement Measurements.

This research examined several possible system changes, concentrating on changes that could be made to the system that would reduce the time Marines spent waiting for training. Some of these changes would require high-level approval for implementation, and others could be implemented by MCCES immediately. For the analysis in this paper, focus was placed primarily on those items that could be changed by the local commander and did not require any capital investment. Therefore, this investigation included using a compacted training cycle, increasing the number of instructor billets currently filled, varying minimum and maximum class sizes, and changing to on-demand class scheduling.

Incorporating on-demand scheduling is a broad change which may require a large paradigm shift for implementation. In on-demand scheduling, a class requires four conditions to be met prior to starting: a minimum number of students, minimum available instructors, one available lecture hall, and one laboratory (if applicable) that will become available by the time the lecture portion of the course is finished.

Switching to an on-demand scheduling process may also have a negative impact on the quality of life for instructors. Because instructors would not know the precise start date of the next class they will proctor, their ability to plan would be impacted. However, if communications between MCRD, MCT, and MCCES are improved, informing MCCES of projected arrivals, instructors could have an approximate schedule of classes to use for decision making.

B. AREAS FOR FURTHER ACTION AND RESEARCH

The simplest change with the largest effect on the process is shifting to an on-demand schedule. The researchers strongly recommend that at the minimum, MCCES convert one MOS to an on-demand schedule and closely follow each Marine from the day of arrival to the day of graduation. The researchers recommend that MOS 0621 immediately go to an on-demand scheduling system because it will have the largest impact on MCCES with approximately 1200 arrivals every year. With an increase of instructor utilization of only 3.5%, the reduction in the average number of 0621 Marines in MAT from 55.472 to 13.243 and a reduction of days spent in MAT from 16.881 to

4.51 days, will illustrate a noticeable difference in facilities usage as well as a significant reduction in the amount of resources needed to manage them while they are in MAT.

There are other changes that could be explored to assess further impacts on waiting times. For example, future models could quantify the effects of incorporating additional lecture and laboratory facilities, further reduction in the number of required training days, increasing available instructors, and a combination of scheduled versus on-demand classes. The research demonstrates the benefits of using modeling and simulation, therefore, the researchers recommend the continued use of modeling and simulation as the primary means to analyze and justify additional capital investment and/or changes to policy.

During the analysis of the data, the researchers noted that the inter-arrival rates for Marines appears to be seasonal and that the lecture and lab classes are scheduled as one process without a wait between portions of the training curriculum. Future iterations of the model should incorporate seasonality and a class-scheduling philosophy—scheduling lecture and lab classes individually, since the lab classroom has been identified as a capacity-limiting resource.

Effective communication between stakeholders, e.g., communications between MCRD, MCT, and MCCES, will be essential to overcoming the complexity of allowing MCCES staff to plan personnel leave periods if the on-demand method of scheduling is implemented. Without having an idea of short-term arrivals, it will be difficult for instructors to plan their annual leave without having a direct effect on the commencement of MOS training courses. However, if MCRD and MCT were to provide their projected arrivals to MCCES, these complications could be minimized and could result in higher levels of staff morale.

Future models should use more historical data to develop forecasting models that, when used in tandem with the simulation model, will allow MCCES to better predict inter-arrival rates, determine the best use of its resources, justify additional changes to the system, or additional capital investment.

Similar process examination and improvement should also be made at MCRD. There are potential improvements that can be modeled and simulated at MCRD that may include changes to recruiting philosophy and possible postponement of MOS decisions fed by Manpower and Reserve Affairs, and communication between Recruiting Command and Training Command that affect the T2 pipeline. These decisions can have a serious affect on formal school performance and may consequently result in wasted resources which translate to fewer Marines in the Operating Forces.

Finally, formal schools should be allowed to independently establish policies that can best support the Operating Forces, e.g., establish minimum and maximum class sizes, determine scheduling method to be used, and not only determine the number of instructors that should be actually assigned, but also receive Marines to fill those billets.

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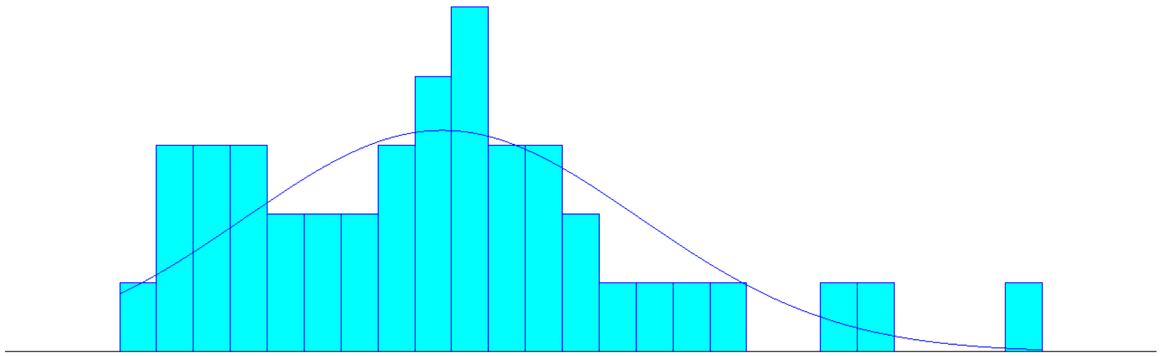
APPENDIX A



0612 Distribution Summary

Distribution:	Normal
Expression:	NORM(9.23, 5.33)
Square Error:	0.008993

Chi Square Test

Number of intervals	= 7
Degrees of freedom	= 4
Test Statistic	= 5.5
Corresponding p-value	= 0.243

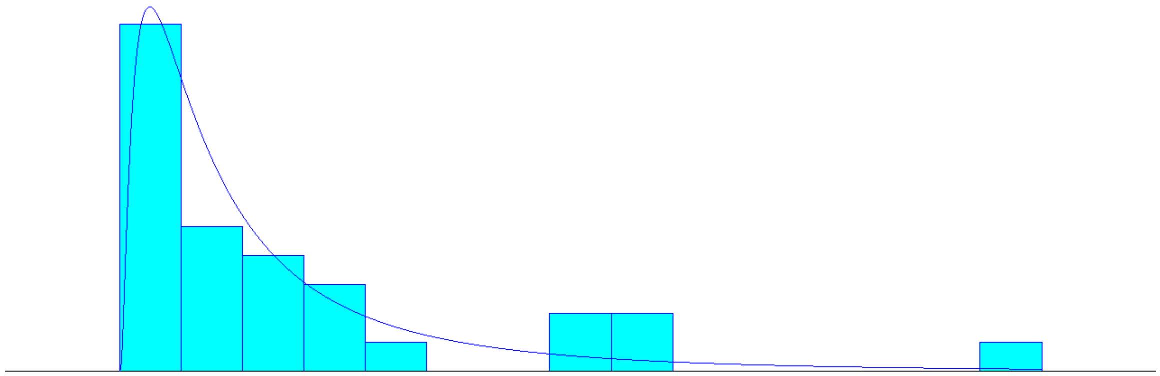
Data Summary

Number of Data Points	= 43
Min Data Value	= 1
Max Data Value	= 25
Sample Mean	= 9.23
Sample Std Dev	= 5.4

Histogram Summary

Histogram Range	= 0.5 to 25.5
Number of Intervals	= 25

Figure 11. MOS 0612 Input Analyzer Arrival Distribution Graph and Statistics.



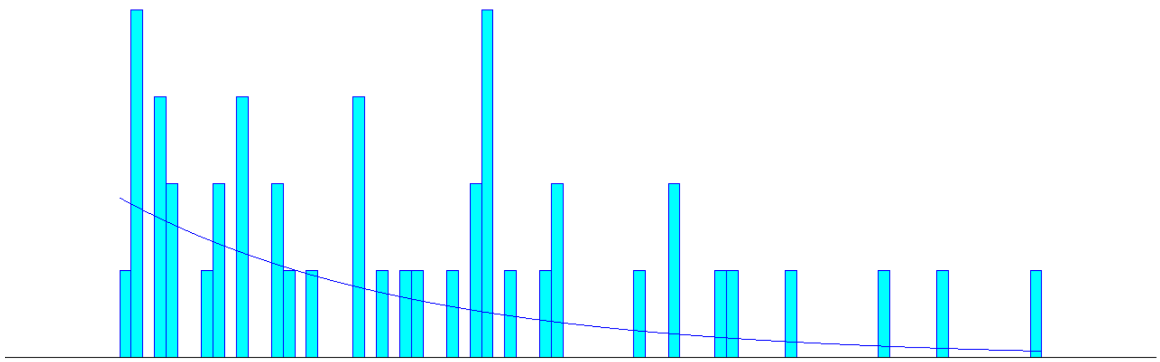
0614 Distribution Summary
Distribution: Lognormal
Expression: 0.5 + LOGN(2.83, 4.22)
Square Error: 0.019772

Chi Square Test
Number of intervals = 4
Degrees of freedom = 1
Test Statistic = 1.31
Corresponding p-value = 0.253

Data Summary
Number of Data Points = 30
Min Data Value = 1
Max Data Value = 15
Sample Mean = 3.33
Sample Std Dev = 3.34

Histogram Summary
Histogram Range = 0.5 to 15.5
Number of Intervals = 15

Figure 12. MOS 0614 Input Analyzer Arrival Distribution Graph and Statistics.



<u>0621 Distribution Summary</u>

Distribution:	Exponential
Expression:	0.5 + EXPO(25)
Square Error:	0.029224

<u>Chi Square Test</u>

Number of intervals	= 8
Degrees of freedom	= 6
Test Statistic	= 7.19
Corresponding p-value	= 0.315

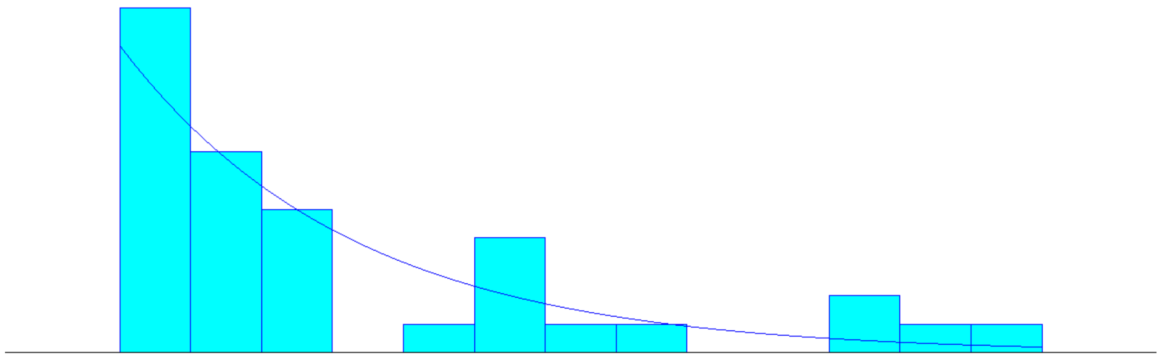
<u>Data Summary</u>

Number of Data Points	= 46
Min Data Value	= 1
Max Data Value	= 79
Sample Mean	= 25.5
Sample Std Dev	= 20.2

<u>Histogram Summary</u>

Histogram Range	= 0.5 to 79.5
Number of Intervals	= 79

Figure 13. MOS 0621 Input Analyzer Arrival Distribution Graph and Statistics.



<u>0622 Distribution Summary</u>

Distribution:	Exponential
Expression:	0.5 + EXPO(3.27)
Square Error:	0.026953

<u>Chi Square Test</u>

Number of intervals	= 5
Degrees of freedom	= 3
Test Statistic	= 6.84
Corresponding p-value	= 0.0813

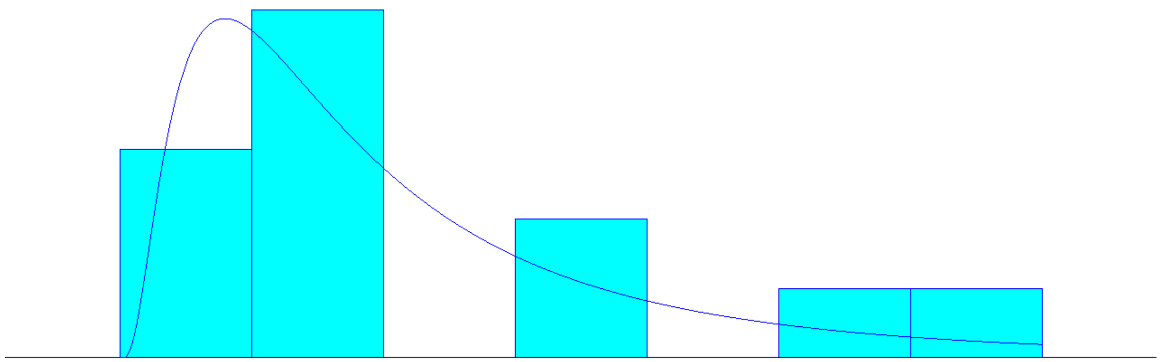
<u>Data Summary</u>

Number of Data Points	= 35
Min Data Value	= 1
Max Data Value	= 13
Sample Mean	= 3.77
Sample Std Dev	= 3.53

<u>Histogram Summary</u>

Histogram Range	= 0.5 to 13.5
Number of Intervals	= 13

Figure 14. MOS 0622 Input Analyzer Arrival Distribution Graph and Statistics.



<u>0623 Distribution Summary</u>

Distribution:	Exponential
Expression:	0.5 + EXPO(2.33)
Square Error:	0.081442

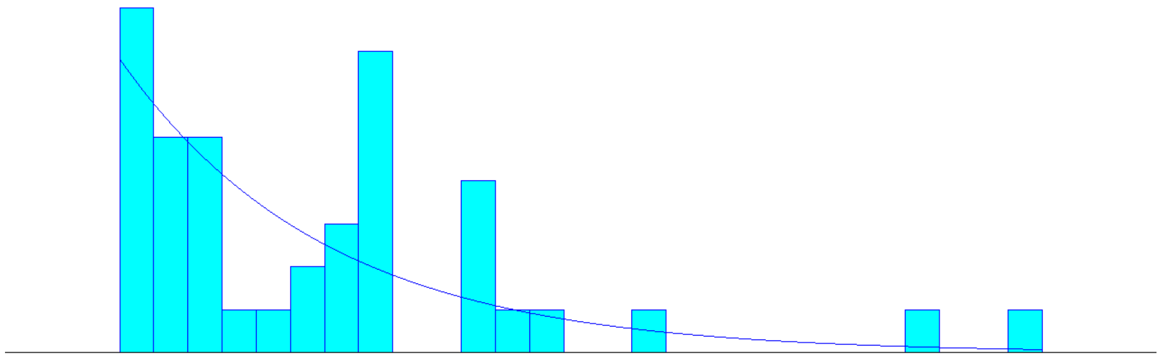
<u>Data Summary</u>

Number of Data Points	= 12
Min Data Value	= 1
Max Data Value	= 7
Sample Mean	= 2.83
Sample Std Dev	= 1.99

<u>Histogram Summary</u>

Histogram Range	= 0.5 to 7.5
Number of Intervals	= 7

Figure 15. MOS 0623 Input Analyzer Arrival Distribution Graph and Statistics.



<u>0651 Distribution Summary</u>

Distribution:	Exponential
Expression:	0.5 + EXPO (6.01)
Square Error:	0.034855

<u>Chi Square Test</u>

Number of intervals	= 6
Degrees of freedom	= 4
Test Statistic	= 5.53
Corresponding p-value	= 0.241

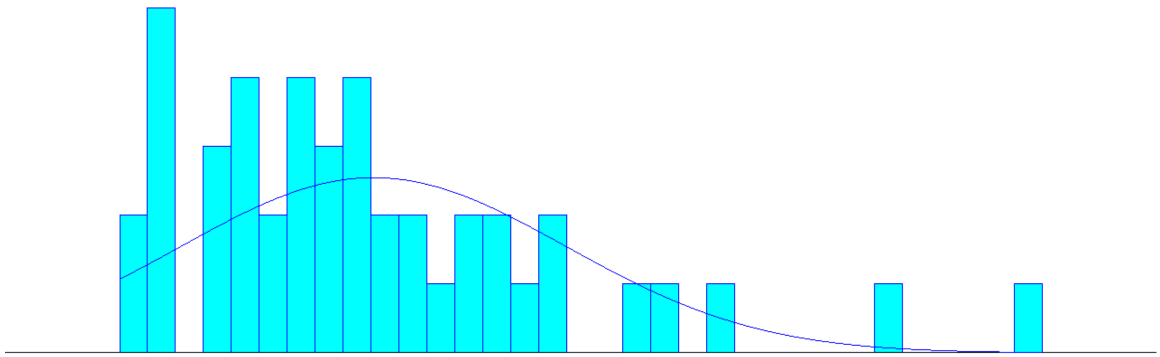
<u>Data Summary</u>

Number of Data Points	= 41
Min Data Value	= 1
Max Data Value	= 27
Sample Mean	= 6.51
Sample Std Dev	= 5.92

<u>Histogram Summary</u>

Histogram Range	= 0.5 to 27.5
Number of Intervals	= 27

Figure 16. MOS 0651 Input Analyzer Arrival Distribution Graph and Statistics.



0656 Distribution Summary

Distribution:	Normal
Expression:	NORM (9.57, 6.9)
Square Error:	0.018772

Chi Square Test

Number of intervals	= 6
Degrees of freedom	= 3
Test Statistic	= 7.94
Corresponding p-value	= 0.048

Data Summary

Number of Data Points	= 44
Min Data Value	= 1
Max Data Value	= 33
Sample Mean	= 9.57
Sample Std Dev	= 6.98

Histogram Summary

Histogram Range	= 0.5 to 33.5
Number of Intervals	= 33

Figure 17. MOS 0656 Input Analyzer Arrival Distribution Graph and Statistics.

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APPENDIX B

MOS 0612 PAN Results					
Scenario	Min Class Size	Max Class Size	Average Days In Mat Queue	Average Number of Marines in Mat Queue	Instructor Utilization
On Demand - 14 days - 7 instructors	14	25	7.184	7.173	0.398
On Demand - 17 days - 7 instructors	14	25	7.299	7.289	0.475
On Demand - 14 days - 7 instructors	14	20	7.641	7.616	0.421
On Demand - 17 days - 7 instructors	14	20	7.912	7.906	0.502
On Demand - 14 days - 7 instructors	20	25	10.563	10.572	0.328
On Demand - 17 days - 7 instructors	20	25	10.576	10.587	0.396
On Demand - 14 days - 7 instructors	20	20	12.175	12.092	0.379
On Demand - 17 days - 7 instructors	20	20	12.313	12.24	0.456
Scheduled - 14 days - 7 instructors	14	25	17.583	17.532	0.331
Scheduled - 17 days - 7 instructors	14	25	17.583	17.532	0.398
Scheduled - 14 days - 7 instructors	20	25	21.62	21.482	0.301
Scheduled - 17 days - 7 instructors	20	25	21.62	21.482	0.364
Scheduled - 14 days - 7 instructors	14	20	24.239	24.162	0.382
Scheduled - 17 days - 7 instructors	**14**	**20**	**24.239**	**24.162**	**0.457**
Scheduled - 14 days - 7 instructors	20	20	29.099	28.943	0.372
Scheduled - 17 days - 7 instructors	20	20	29.099	28.943	0.445

Table 12. MOS 0612 Process Analyzer Results. [12]

[12] Bold indicates policy in use.

MOS 0614 PAN Results					
Scenario	Min Class Size	Max Class Size	Average Days In Mat Queue	Average Number of Marines in Mat Queue	Instructor Utilization
On Demand - 28 days - 6 instructors	5	12	12.736	3.011	0.52
On Demand - 28 days - 4 instructors	5	12	12.736	3.011	0.779
On Demand - 28 days - 6 instructors	5	10	14.39	3.507	0.538
On Demand - 28 days - 4 instructors	5	10	14.39	3.507	0.808
On Demand - 40 days - 6 instructors	5	12	17.503	4.392	0.688
On Demand - 40 days - 4 instructors	5	12	17.503	4.392	1.032
On Demand - 40 days - 6 instructors	5	10	21.861	5.679	0.711
On Demand - 40 days - 4 instructors	5	10	21.861	5.679	1.066
On Demand - 28 days - 6 instructors	10	12	24.023	5.343	0.361
On Demand - 28 days - 4 instructors	10	12	24.023	5.343	0.541
On Demand - 40 days - 6 instructors	10	12	26.854	6.231	0.505
On Demand - 40 days - 4 instructors	10	12	26.854	6.231	0.758
On Demand - 28 days - 6 instructors	10	10	27.306	6.197	0.401
On Demand - 28 days - 4 instructors	10	10	27.306	6.197	0.602
On Demand - 40 days - 6 instructors	10	10	32.701	7.855	0.562
On Demand - 40 days - 4 instructors	10	10	32.701	7.855	0.842
Scheduled - 28 days - 6 instructors	5	12	40.129	9.66	0.392
Scheduled - 40 days - 6 instructors	5	12	40.129	9.66	0.566
Scheduled - 28 days - 4 instructors	5	12	40.129	9.66	0.583
Scheduled - 40 days - 4 instructors	5	12	40.129	9.66	0.829
Scheduled - 28 days - 6 instructors	5	10	48.953	12.117	0.437
Scheduled - 40 days - 6 instructors	5	10	48.953	12.117	0.632
Scheduled - 28 days - 4 instructors	5	10	48.953	12.117	0.645
Scheduled - 40 days - 4 instructors	**5**	**10**	**48.953**	**12.117**	**0.91**
Scheduled - 28 days - 6 instructors	10	12	54.202	12.69	0.344
Scheduled - 40 days - 6 instructors	10	12	54.202	12.69	0.497
Scheduled - 28 days - 4 instructors	10	12	54.202	12.69	0.512
Scheduled - 40 days - 4 instructors	10	12	54.202	12.69	0.729
Scheduled - 28 days - 6 instructors	10	10	65.506	15.637	0.405
Scheduled - 40 days - 6 instructors	10	10	65.506	15.637	0.584
Scheduled - 28 days - 4 instructors	10	10	65.506	15.637	0.599
Scheduled - 40 days - 4 instructors	10	10	65.506	15.637	0.844

Table 13. MOS 0614 Process Analyzer Results.[13]

[13] Bold indicates policy in use.

MOS 0621 PAN Results					
Scenario	Min Class Size	Max Class Size	Average Days In Mat Queue	Average Number of Marines in Mat Queue	Instructor Utilization
On Demand - 24 days - 27 instructors	20	50	4.399	12.912	0.244
On Demand - 24 days - 25 instructors	20	50	4.399	12.912	0.263
On Demand - 30 days - 27 instructors	20	50	4.406	12.936	0.3
On Demand - 30 days - 25 instructors	20	50	4.406	12.936	0.324
On Demand - 24 days - 27 instructors	20	45	4.498	13.2	0.255
On Demand - 24 days - 25 instructors	20	45	4.498	13.2	0.275
On Demand - 30 days - 27 instructors	20	45	4.51	13.243	0.313
On Demand - 30 days - 25 instructors	20	45	4.51	13.243	0.338
On Demand - 24 days - 27 instructors	45	50	9.541	27.736	0.188
On Demand - 24 days - 25 instructors	45	50	9.541	27.736	0.203
On Demand - 30 days - 27 instructors	45	50	9.542	27.74	0.231
On Demand - 30 days - 25 instructors	45	50	9.542	27.74	0.249
On Demand - 24 days - 27 instructors	45	45	10	29.139	0.205
On Demand - 24 days - 25 instructors	45	45	10	29.139	0.221
On Demand - 30 days - 27 instructors	45	45	10.006	29.161	0.251
On Demand - 30 days - 25 instructors	45	45	10.006	29.161	0.272
Scheduled - 30 days - 25 instructors	20	50	13.765	46.903	0.288
Scheduled - 24 days - 27 instructors	20	50	13.785	46.903	0.216
Scheduled - 24 days - 27 instructors	45	50	13.785	46.903	0.216
Scheduled - 24 days - 25 instructors	20	50	13.785	46.903	0.233
Scheduled - 24 days - 25 instructors	45	50	13.785	46.903	0.233
Scheduled - 30 days - 27 instructors	20	50	13.785	46.903	0.266
Scheduled - 30 days - 27 instructors	45	50	13.785	46.903	0.266
Scheduled - 30 days - 25 instructors	45	50	13.785	46.903	0.288
Scheduled - 30 days - 27 instructors	20	45	16.681	55.472	0.28
Scheduled - 24 days - 27 instructors	20	45	16.881	55.472	0.227
Scheduled - 24 days - 25 instructors	20	45	16.881	55.472	0.245
Scheduled - 30 days - 25 instructors	**20**	**45**	**16.881**	**55.472**	**0.303**
Scheduled - 24 days - 27 instructors	45	45	22.776	72.789	0.201
Scheduled - 24 days - 25 instructors	45	45	22.776	72.789	0.217
Scheduled - 30 days - 27 instructors	45	45	22.776	72.789	0.249
Scheduled - 30 days - 25 instructors	45	45	22.776	72.789	0.268

Table 14. MOS 0621 Process Analyzer Results. [14]

[14] Bold indicates policy in use.

MOS 0622 PAN Results					
Scenario	Min Class Size	Max Class Size	Average Days In Mat Queue	Average Number of Marines in Mat Queue	Instructor Utilization
On Demand - 24 days - 3 instructors	10	30	14.797	4.3	0.295
On Demand - 24 days - 3 instructors	10	27	14.826	4.309	0.295
On Demand - 30 days - 3 instructors	10	30	14.893	4.335	0.367
On Demand - 30 days - 3 instructors	10	27	14.918	4.343	0.368
On Demand - 24 days - 3 instructors	20	27	31.264	9.064	0.169
On Demand - 30 days - 3 instructors	20	27	31.264	9.064	0.211
On Demand - 24 days - 3 instructors	20	30	31.319	9.081	0.168
On Demand - 30 days - 3 instructors	20	30	31.319	9.081	0.209
Scheduled - 24 days - 3 instructors	10	30	35.23	10.252	0.191
Scheduled - 30 days - 3 instructors	10	30	35.23	10.252	0.232
Scheduled - 24 days - 3 instructors	10	27	37.115	10.962	0.193
Scheduled - 30 days - 3 instructors	10	27	37.115	10.962	0.234
On Demand - 24 days - 3 instructors	27	30	44.59	12.94	0.133
On Demand - 30 days - 3 instructors	27	30	44.59	12.94	0.166
On Demand - 24 days - 3 instructors	27	27	47.272	13.664	0.141
On Demand - 30 days - 3 instructors	27	27	47.272	13.664	0.176
Scheduled - 24 days - 3 instructors	20	30	52.087	15.167	0.147
Scheduled - 30 days - 3 instructors	20	30	52.087	15.167	0.178
Scheduled - 24 days - 3 instructors	20	27	56.218	16.441	0.155
Scheduled - 30 days - 3 instructors	**20**	**27**	**56.218**	**16.441**	**0.188**
Scheduled - 24 days - 3 instructors	27	30	71.598	20.802	0.134
Scheduled - 30 days - 3 instructors	27	30	71.598	20.802	0.162
Scheduled - 24 days - 3 instructors	27	27	75.837	22.098	0.147
Scheduled - 30 days - 3 instructors	27	27	75.837	22.098	0.177

Table 15. MOS 0622 Process Analyzer Results. [15]

[15] Bold indicates policy in use.

MOS 0623 PAN Results					
Scenario	Min Class Size	Max Class Size	Average Days In Mat Queue	Average Number of Marines in Mat Queue	Instructor Utilization
On Demand - 21 days - 3 instructors	5	15	23.564	1.934	0.141
On Demand - 21 days - 3 instructors	5	13	23.679	1.955	0.142
On Demand - 31 days - 3 instructors	5	15	27.437	2.343	0.197
On Demand - 31 days - 3 instructors	5	13	28	2.412	0.199
On Demand - 21 days - 3 instructors	10	15	51.462	4.129	0.085
On Demand - 31 days - 3 instructors	10	15	52.14	4.232	0.125
On Demand - 21 days - 3 instructors	10	13	52.941	4.238	0.087
On Demand - 31 days - 3 instructors	10	13	53.965	4.393	0.128
On Demand - 21 days - 3 instructors	13	15	71.339	5.772	0.071
On Demand - 31 days - 3 instructors	13	15	71.847	5.836	0.105
Scheduled - 21 days - 3 instructors	5	15	74.739	5.969	0.103
Scheduled - 31 days - 3 instructors	5	15	74.739	5.969	0.154
On Demand - 21 days - 3 instructors	13	13	76.543	6.231	0.076
On Demand - 31 days - 3 instructors	13	13	77.424	6.348	0.112
Scheduled - 21 days - 3 instructors	5	13	80.513	6.633	0.108
Scheduled - 31 days - 3 instructors	5	13	80.513	6.633	0.161
Scheduled - 21 days - 3 instructors	10	15	103.178	8.314	0.082
Scheduled - 31 days - 3 instructors	10	15	103.178	8.314	0.122
Scheduled - 21 days - 3 instructors	10	13	112.513	9.308	0.089
Scheduled - 31 days - 3 instructors	**10**	**13**	**112.513**	**9.308**	**0.132**
Scheduled - 21 days - 3 instructors	13	15	125.932	10.265	0.076
Scheduled - 31 days - 3 instructors	13	15	125.932	10.265	0.113
Scheduled - 21 days - 3 instructors	13	13	139.872	11.499	0.086
Scheduled - 31 days - 3 instructors	13	13	139.872	11.499	0.127

Table 16. MOS 0623 Process Analyzer Results. [16]

[16] Bold indicates policy in use.

MOS 0651 PAN Results					
Scenario	Min Class Size	Max Class Size	Average Days In Mat Queue	Average Number of Marines in Mat Queue	Instructor Utilization
On Demand - 32 Days - 16 instructors	10	30	7.259	4.559	0.3
On Demand - 40 Days - 16 instructors	10	30	7.259	4.559	0.367
On Demand - 32 Days - 11 instructors	10	30	7.259	4.559	0.437
On Demand - 40 Days - 11 instructors	10	30	7.26	4.561	0.534
On Demand - 40 days - 16 instructors	15	30	11.046	6.919	0.286
On Demand - 32 days - 16 instructors	15	30	11.046	6.919	0.286
On Demand - 40 days - 11 instructors	15	30	11.046	6.919	0.416
On Demand - 32 days - 11 instructors	15	30	11.046	6.919	0.416
Scheduled - 32 days - 16 instructors	10	30	17.480	11.184	0.230
Scheduled - 40 days - 16 instructors	10	30	17.48	11.184	0.281
Scheduled - 32 days - 11 instructors	10	30	17.480	11.184	0.335
Scheduled - 40 days - 11 instructors	10	30	17.48	11.184	0.409
Scheduled - 32 days - 16 instructors	15	30	21.112	13.43	0.2
Scheduled - 40 days - 16 instructors	**15**	**30**	**21.112**	**13.43**	**0.245**
Scheduled - 32 days - 11 instructors	15	30	21.112	13.43	0.291
Scheduled - 40 days - 11 instructors	15	30	21.112	13.43	0.356
On Demand - 40 days - 16 instructors	30	30	25.617	16.109	0.201
On Demand - 32 days - 16 instructors	30	30	25.617	16.109	0.201
On Demand - 40 days - 11 instructors	30	30	25.617	16.109	0.293
On Demand - 32 days - 11 instructors	30	30	25.617	16.109	0.293
Scheduled - 32 days - 16 instructors	30	30	37.912	23.913	0.163
Scheduled - 40 days - 16 instructors	30	30	37.912	23.913	0.201
Scheduled - 32 days - 11 instructors	30	30	53.212	34.063	0.339
Scheduled - 40 days - 11 instructors	30	30	53.212	34.063	0.416

Table 17. MOS 0651 Process Analyzer Results.[17]

[17] Bold indicates policy in use.

MOS 0656 PAN Results					
Scenario	Min Class Size	Max Class Size	Average Days In Mat Queue	Average Number of Marines in Mat Queue	Instructor Utilization
On Demand - 32 days - 12 instructors	15	27	5.505	5.901	0.468
On Demand - 32 days - 10 instructors	15	27	5.505	5.901	0.562
On Demand - 32 days - 10 instructors	18	27	6.812	7.278	0.511
On Demand - 32 days - 12 instructors	18	27	6.814	7.28	0.425
On Demand - 41 days - 10 instructors	15	27	7.52	8.184	0.684
On Demand - 41 days - 12 instructors	15	27	7.52	8.185	0.57
On Demand - 41 days - 12 instructors	18	27	8.176	8.845	0.53
On Demand - 41 days - 10 instructors	18	27	8.176	8.846	0.636
On Demand - 32 days - 10 instructors	15	18	10.106	11.108	0.666
On Demand - 32 days - 12 instructors	15	18	10.106	11.108	0.666
On Demand - 32 days - 12 instructors	18	18	12.253	13.379	0.544
On Demand - 32 days - 10 instructors	18	18	12.286	13.417	0.653
Scheduled - 41 days - 12 instructors	15	27	21.805	23.661	0.502
Scheduled - 41 days - 10 instructors	15	27	21.805	23.661	0.603
Scheduled - 32 days - 12 instructors	15	27	21.919	23.778	0.403
Scheduled - 32 days - 10 instructors	15	27	21.919	23.778	0.483
Scheduled - 41 days - 12 instructors	18	27	23.396	25.347	0.491
Scheduled - 41 days - 10 instructors	18	27	23.396	25.347	0.589
Scheduled - 32 days - 12 instructors	18	27	23.451	25.411	0.393
Scheduled - 32 days - 10 instructors	18	27	23.451	25.411	0.471
On Demand - 41 days - 12 instructors	15	18	42.779	47.788	0.665
On Demand - 41 days - 10 instructors	15	18	43.542	48.611	0.808
On Demand - 41 days - 12 instructors	18	18	43.905	48.964	0.662
On Demand - 41 days - 10 instructors	18	18	44.699	49.824	0.803
Scheduled - 41 days - 12 instructors	**15**	**18**	**86.706**	**95.385**	**0.648**
Scheduled - 41 days - 10 instructors	15	18	86.706	95.385	0.778
Scheduled - 32 days - 12 instructors	15	18	86.808	95.483	0.515
Scheduled - 32 days - 10 instructors	15	18	86.808	95.483	0.618
Scheduled - 41 days - 12 instructors	18	18	87.466	96.168	0.648
Scheduled - 41 days - 10 instructors	18	18	87.466	96.168	0.777
Scheduled - 32 days - 12 instructors	18	18	87.559	96.263	0.515
Scheduled - 32 days - 10 instructors	18	18	87.559	96.263	0.618

Table 18. MOS 0656 Process Analyzer Results.[18]

[18] Bold indicates policy in use.

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APPENDIX C

MOS 0612		
Rank	**Composite Rate**	**Total by Rank**
E-1	$35,005	229
E-2	$38,711	147
E-3	$42,623	11
E-4	$48,589	21
E-5	$57,537	3
E-6	$68,591	0
Total		411
Weighted Average Salary		$37,392.93
OMB Daily Rate (.00439 Factor)		$164.15

MOS 0623		
Rank	**Composite Rate**	**Total by Rank**
E-1	$35,005	51
E-2	$38,711	20
E-3	$42,623	0
E-4	$48,589	0
E-5	$57,537	0
E-6	$68,591	0
Total		71
Weighted Average Salary		$36,048.94
OMB Daily Rate (.00439 Factor)		$158.25

MOS 0614		
Rank	**Composite Rate**	**Total by Rank**
E-1	$35,005	55
E-2	$38,711	32
E-3	$42,623	3
E-4	$48,589	3
E-5	$57,537	3
E-6	$68,591	0
Total		96
Weighted Average Salary		$37,607.02
OMB Daily Rate (.00439 Factor)		$165.09

MOS 0651		
Rank	**Composite Rate**	**Total by Rank**
E-1	$35,005	117
E-2	$38,711	143
E-3	$42,623	1
E-4	$48,589	33
E-5	$57,537	6
E-6	$68,591	2
Total		302
Weighted Average Salary		$38,939.48
OMB Daily Rate (.00439 Factor)		$170.94

MOS 0621		
Rank	**Composite Rate**	**Total by Rank**
E-1	$35,005	759
E-2	$38,711	434
E-3	$42,623	34
E-4	$48,589	17
E-5	$57,537	10
E-6	$68,591	1
Total		1255
Weighted Average Salary		$36,883.29
OMB Daily Rate (.00439 Factor)		$161.92

MOS 0656		
Rank	**Composite Rate**	**Total by Rank**
E-1	$35,005	129
E-2	$38,711	198
E-3	$42,623	11
E-4	$48,589	8
E-5	$57,537	18
E-6	$68,591	0
Total		364
Weighted Average Salary		$38,663.88
OMB Daily Rate (.00439 Factor)		$169.73

MOS 0622		
Rank	**Composite Rate**	**Total by Rank**
E-1	$35,005	77
E-2	$38,711	58
E-3	$42,623	4
E-4	$48,589	1
E-5	$57,537	1
E-6	$68,591	0
Total		141
Weighted Average Salary		$37,001.71
OMB Daily Rate (.00439 Factor)		$162.44

Table 19. OMB Daily Rate Computations by MOS.

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APPENDIX D

	Cost Attributed to Each MOS				
MOS	Annual Facilities Dorms/Barracks	Annual Base Support Costs	Cost Per Day (365 day year)	Course Throughput	Cost Per Day Per Marine
0612	$42,487.00	$4,646,164.00	$12,845.62	518.00	$24.80
0614	$9,514.00	$1,040,454.00	$2,876.62	130.50	$22.04
0621	$142,990.00	$15,636,776.00	$43,232.24	1,800.50	$24.01
0622	$26,783.00	$2,928,875.00	$8,097.69	278.00	$29.13
0623	Data Not Available				
0651	$66,442.00	$7,265,807.00	$20,088.35	750.50	$26.77
0656	$44,834.00	$4,902,861.00	$13,555.33	441.50	$30.70

Table 20. Base Costs Attributed to Each MOS.

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